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To CLERK, 1ST GRADE

GEN. 153

THE SYDNEY COUNTY COUNCIL

BRANCH STANDING INSTRUCTION

No. 1037
Index No. 614.323 614.324
Date 10/11/52.

M.S./C.McG.

SECTIONAL (Procedure)

BRANCH METER.

SECTION MAINTENANCE & SERVICE

SUBJECT METER TESTING - FIELD TESTING OF LOW VOLTAGE POLYPHASE WATTHOUR METERS, TYPE EMMCO SD.

OBJECTIVE To set out the procedure to be observed by staff when testing low voltage 3-phase 4-wire and 2-phase 3-wire Emmco type SD polyphase watthour meters in the field.

MEANS OF ATTAINMENT.

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1. Preliminary Procedure.

(a) Check and record, where necessary, particulars of address, meter number, type, size, constant, and reading of meter. In checking the address, any additional information which may assist in locating meters at subsequent visits, or information such as "savage dog", "meters accessible only by long ladder", etc., shall be recorded also on the Test Card.

Where demand meters are connected, the readings of the maximum demand indicators are to be noted and care taken that they are not altered; any apparent defects in maximum demand indicators shall be reported.

(b) Check by means of test lamps if active or neutral conductor of the meter is alive to frame. Test from the grid of the meter to earth, and from each of the line (active) conductors to the grid of the meter.

(c) Generally inspect the meter, seals, and conductors, and clean the meter cover.

(d) Check metering connections (see diagram of connections attached to this Instruction). Any incorrect metering connections found shall be reported to the supervisor.

(e) Check for evidence of illegal interference with meter, such as hole in cover, bridges on conductors, damaged seals, etc. If interference is apparent, communicate promptly with the Supervisor. (For procedure, see B.S.I. No. 1010, Meter Testing - Illegal Interference with Meters). In any case of apparent interference, the meter seals are to be retained.

(f) Check phase rotation. This shall be carried out by using the static phase rotation indicator (lamp type) by connecting as follows:-

(i) Whole Current or Direct Connected Meters - 3-Phase 4-Wire.

The red lead or that marked No. 1 to the No. 1 or left-hand terminal of the meter or test block, the yellow lead or that marked No. 2 to the No. 3 terminal of the meter or test block, and the blue lead or that marked No. 3 to the No. 5 terminal of the meter or test block. The direction of phase rotation will be indicated by whichever is the brighter lamp. Vector diagrams shown immediately under each lamp indicate the direction for the particular lamp.

1. (f) (ii) Whole Current or Direct Connected Meters - 2-Phase 3-Wire.

The No. 2 or yellow lead of the phase rotation indicator to the neutral terminal of the test block or meter, the No. 1 or red lead to the left-hand or No. 1 terminal of the meter or test block, and the No. 3 or blue lead to the No. 5 terminal of the meter or test block. If the left-hand lamp pf the phase rotation indicator is bright and the right-hand lamp dull, the active conductor connected to the No. 1 or red lead is leading the active conductor connected to the No. 3 or blue lead, i.e. the rotation can be taken as clockwise. (See diagram of connections No. 2 attached).

(iii) Current Transformer Meters.

The red lead or that marked No. 1 to the No. 1 or left-hand voltage terminal of the meter or test block, the yellow lead or that marked No. 2 to the middle voltage terminal of the meter or test block, and the blue lead or that marked No. 3 to the right-hand voltage terminal of the meter or test block. (See diagram of connections No. 3 attached).

It is important that the rotation be clockwise. If the rotation is found to be incorrect, the connection shall be altered, if practicable, to clockwise rotation. If not practicable, a report shall be forwarded to the supervisor who shall arrange with the Chief Installation Inspector to correct the connection. The metering connections shall not be altered, however, before the "as found" test is carried out on the meter, but shall be altered before recalibrating the meter.

2. Testing Procedure - 3-Phase 4-Wire Whole Current or Direct Connected Meters.

(a) General Procedure Depending upon Size.

10/30 ampere meters shall be tested in the field as a routine procedure. Such tests shall be carried out only by Special Meter Inspectors. 50/100 amp. meters shall not be tested in the field as a routine procedure, except in cases where the accuracy is queried by the customer. Where such meters are due for routine test, they shall be changed and tested in the Meter Test Room.

(b) Test Procedure.

The meters shall be tested by testing each element separately, using a modified standard field test equipment. Before proceeding to test the meters, bridge the customer's load by inserting plugs at positions 2A, 2B and 2C. Remove plugs from positions 1A, 1B and 1C (see diagram of connections No. 1 attached).

To test the No. 1 or red phase element of the meter, connect the line or active lead from the testing equipment at socket position 3A, the load lead at position 4A, and the neutral at position 6N. To test the No. 2 or yellow phase element of the meter, connect the line or active lead from the testing equipment to socket position 3B, the load lead to position 4B, and the neutral at position 6N. To test the No. 3 or blue phase element of the meter, socket positions 3C, 4C and 6N shall be used.

2. (c) Creep.

Before connecting test equipment leads, and after having bridged the customer's load and removed the plug from positions 1A, 1B and 1C, check the meter for creep. If meter is found to be creeping either backward or forward, the time for one complete revolution of the meter disc shall be taken, and the kWh due to the creep calculated and recorded, as set out in B.S.I. No. 603, Technical - Meter Testing Formulae.

(d) "As Found" Tests.

"As found" tests shall be carried out in all cases and recorded, even though the meter may be found to be creeping. The "as found" test shall be carried out before adjusting for creep.

(e) Starting Load.

Test any individual element for starting load which shall be not greater than 1.5% Full Load. Meter must complete one full revolution of the disc. Record the starting load.

(f) Light Load Test.

Test each element at 15% Full Load, Unity Power Factor, not less than two revolutions of the disc to be counted. Note the "as found" errors, but make no adjustments. The average error of the three elements (not the test results of the individual elements) shall be recorded on the Test Card, under the 5% Full Load heading. This test should indicate the condition of the meter bearings and register.

(g) Full Load Test.

Test each element at 200% Full Load, Unity Power Factor, not less than 10 revolutions of the disc to be counted. Note the "as found" error. No adjustments to be made. The average error of the three elements (not the test results of the individual elements) shall be recorded on the Test Card under the 100% Full Load heading.

(h) Average Accuracy.

The average accuracy of the meter shall be calculated and recorded according to the class of customer, as set out in B.S.I. No. 1025, Meter Testing - Calculation of Meter Accuracy.

(i) Limits of "As Found" Error for the Purpose of Recalibration.

Until further notice, meters tested in the field shall be recalibrated when the "as found" error of any of the individual elements at any of the test loads exceeds 1.5%, the difference between full load and light load error exceeds 2.5%, or the errors for individual elements at any particular test load differ by more than 0.7%.

2. (j) Conditions under which Bearings shall be Changed.

Where it is necessary to change the bearings, all bearings shall be changed, i.e. both top and bottom.

Bearings of meters shall be changed in the following cases -

(i) Where previous test results shown on the Test Card indicate that the bearings have not been changed during the previous three (3) years.

(ii) Where the "as found" error of any of the individual elements at any of the test loads is found to be in excess of 1.5%-, or the difference between the low load error and the full load error of any of the individual elements exceeds 2.5%.

(iii) The test results, when compared with the two previous test results shown on the Test Card, indicate an increasingly slow error at light load.

(k) Lubrication.

(i) Bottom Bearings.

The bottom bearings shall be lubricated with the lubricant provided for the purpose. The lubricant shall be applied to the replacement pivot in such a way as to ensure that only a small film of oil remains on the pivot. No lubricant shall be placed in the replacement jewel.

(ii) Top Bearings.

Top bearings shall be lubricated with the heavy lubricant provided. Where the bearings are replaced, replacement bearings shall be likewise lubricated.

(iii) Registers.

Registers shall not be lubricated.

(l) Checking of Registers.

(i) Query Testing.

The register shall be visually checked for loose dial pointer, split pinions and correct meshing. In addition to the visual check, the register, when replaced, shall be checked for ratio by applying load to any one element of the meter until one-tenth of a unit is recorded on the register.

The number of revolutions of the disc of the meter to register the one-tenth of a unit shall be checked to ensure that the ratio of the register is correct.

When meters are being checked for under-registration and the Meter Inspector is able to ascertain the reason for the low registration, it will not be necessary to visually check the register. The register shall be checked by applying load.

2. (l) (ii) Periodic Testing.

The register of the meter shall be checked by applying load. In cases where it is necessary to open the meter for any purpose, the register shall be visually checked, in addition to checking the ratio by applying load.

(m) Cleaning of Registers.

Registers of this type of meter have not been lubricated and must not be lubricated at any time. It is not necessary that they be cleaned when tests are carried out.

(n) Recalibration.

Adjust, if necessary, and recalibrate each element of the meter at 200% Full Load, Unity Power Factor, not less than 10 revolutions of the meter disc to be counted. Record "as left" error, which shall be the average of the three elements.

The meter shall be recalibrated by first passing 200% Full Load current at Unity Power Factor through the No. 2 or yellow phase element alone. Adjust within the limits of accuracy by the brake magnet. Calibrate the No. 1 or red phase element and the No. 3 or blue phase element in turn by the balance adjustment to approximate the No. 2 or yellow phase element.

Adjust, if necessary, and recalibrate each element of the meter at 15% Full Load, Unity Power Factor, not less than two revolutions of the meter disc to be counted. Record "as left" error which shall be the average of the three elements. If wide adjustment is necessary, recalibrate meter, as above.

If meter is erratic at the 15% load test, check at this load, with and without the register. Check and record the reading of the meter and also maximum demand indicators, if connected.

Check meter for starting load. Remove test leads, insert plugs in positions 1A, 1B and 1C, ensuring that they are tight, and remove plugs from positions 2A, 2B and 2C (see diagram of connections No. 1 attached). Replace test block cover, reseal meter and test block cover, and leave supply in order.

(o) Limits of Error.

The meter should be calibrated to a degree of accuracy as high as practicable. Meters must be calibrated to fall within the following limits of error:-

Load (Individual Elements)	Power Factor	% Limits of Error
At 15% Full Load	Unity	0.5 ±
At 200% " "	"	0.7 - to 1.0 +

Balance of Elements. The limits of error at light or full load tests between individual elements shall not be greater than 0.7%.

2. (p) Recording of Test Results.

The arithmetical average of the three individual elements of the meter at each of the test loads shall be calculated, and this value only recorded on the Test Card.

(q) Calculation of Average Accuracy.

The average accuracy of the meter shall be calculated as set out in B.S.I. No. 1025, Meter Testing - Calculation of Meter Accuracy, using the average test results as indicated in (p) above.

3. Testing Procedure - 2-Phase 3-Wire Whole Current or Direct Connected Meters.

(a) General Procedure, depending upon Size.

10/30 ampere meters shall be tested in the field as a routine procedure, and such tests shall be carried out only by Special Meter Inspectors. 50/70 ampere meters shall not be tested in the field as a routine procedure, except in cases where the accuracy is queried by the customer. Where such meters are due for routine test, they shall be changed and tested in the Meter Test Room.

(b) Test Procedure.

The meters shall be tested by testing each element separately, using a modified standard field test equipment. Before proceeding to test the meters, bridge the customer's load by inserting plugs at positions 2A and 2C. Remove plugs from positions 1A and 1C (see diagram of connections No. 2 attached).

To test the No. 1 or left hand element of the meter, connect the line or active lead of the testing equipment at socket position 3A, the load lead at position 4A, and the neutral at position 6N. To test the No. 2 or right hand element of the meter, connect the line or active lead from the testing equipment at socket position 3C, the load lead at position 4C, and the neutral at position 6N.

(c) Creep.

Before connecting test equipment leads and after having bridged the customer's load and removed the plugs from positions 1A and 1C, check the meter for creep. If the meter is found to be creeping either backward or forward, the time for one complete revolution of the meter disc shall be taken and the kilowatthours due to creep calculated and recorded, as set out in B.S.I. No. 1603, Technical - Meter Testing Formulae.

(d) "As found" Tests.

"As found" tests shall be carried out in all cases and recorded, even though the meter may be found to be creeping. "As found" tests shall be carried out before adjusting for creep.

3. (e) Starting Load.

Test for starting load on either element, which shall be not greater than 1% Full Load. The meter must complete one full revolution of the disc. Record starting load.

(f) Light Load Test.

Test each element at 10% Full Load, Unity Power Factor, not less than two revolutions of the disc to be counted. Note "as found" error, but make no adjustments. The average error of the two elements shall be recorded on the Test Card, under the 5% Full Load heading. The test result of the individual elements shall not be recorded.

This test should indicate the condition of the meter bearings and register.

(g) Full Load Test.

Test each element at 200% Full Load, Unity Power Factor, not less than 10 revolutions of the disc to be counted. Note the "as found" error. No adjustments to be made. The average error of the two elements shall be recorded on the Test Card under the 100% Full Load heading. The test results of the individual elements shall not be recorded.

(h) Average Accuracy.

The average accuracy of the meter shall be calculated and recorded according to the class of customer, as set out in B.S.I. No. 1025, Meter Testing - Calculation of Meter Accuracy.

(i) Limits of "As found" Error, for the Purpose of Recalibration.

Until further notice, meters tested in the field shall be recalibrated when the "as found" error of any of the individual elements at any of the test loads exceeds 1.5%, the difference between full load and light load error exceeds 2.5%, or the errors for individual elements at any particular test load differ by more than 0.7%.

(j) Conditions under which Bearings shall be Changed.

Where it is necessary to change the bearings, all bearings shall be changed, i.e. both top and bottom.

Bearings of meters shall be changed in the following cases -

(i) Where previous test results shown on the Test Card indicate that the bearings have not been changed during the previous three (3) years.

(ii) Where the "as found" error of any of the individual elements at any of the test loads is found to be in excess of 1.5%, or the difference between the low load error and the full load error of any of the individual elements exceeds 2.5%.

(iii) The test results, when compared with the two previous test results shown on the Test Card, indicate an increasingly slow error at light load.

3. (k) Lubrication.

(i) Bottom Bearings.

The bottom bearings shall be lubricated with the lubricant provided for the purpose. The lubricant shall be applied to the replacement pivot in such a way as to ensure that only a small film of oil remains on the pivot. No lubricant shall be placed in the replacement jewel.

(ii) Top Bearings.

Top bearings shall be lubricated with the heavy lubricant provided. Where the bearings are replaced, replacement bearings shall be likewise lubricated.

(iii) Registers.

Registers shall not be lubricated.

(l) Checking of Registers.

(i) Query Testing.

The register shall be visually checked for loose dial pointer, split pinions and correct meshing. In addition to the visual check, the register, when replaced, shall be checked for ratio by applying load to any one element of the meter until one-tenth of a unit is recorded on the register.

The number of revolutions of the disc of the meter to register the one-tenth of a unit shall be checked to ensure that the ratio of the register is correct.

When meters are being checked for under-registration and the Meter Inspector is able to ascertain the reason for the low registration, it will not be necessary to visually check the register. The register shall be checked by applying load.

(ii) Periodic Testing.

The register of the meter shall be checked by applying load. In cases where it is necessary to open the meter for any purpose, the register shall be visually checked, in addition to checking the ratio by applying load.

(m) Cleaning of Registers.

Registers of this type of meter have not been lubricated and must not be lubricated at any time. It is not necessary that they be cleaned when tests are carried out.

(n) Recalibration.

Adjust, if necessary, and calibrate each element of the meter at 200% Full Load, Unity Power Factor, not less than 10 revolutions of the meter disc to be counted. Record "as left" error which shall be the average of the two elements. The meter shall be recalibrated by passing 200% Full Load current at Unity Power Factor through the No. 1 or left hand

3. (n) Recalibration (Cont'd.).

element. Adjust within the limits of accuracy by the brake magnet. Calibrate the No. 2 or right hand element by the balance adjustment to approximate the No. 1 or left hand element. Adjust, if necessary, and recalibrate each element of the meter at 10% Full Load, Unity Power Factor, not less than two revolutions of the meter disc to be counted. Record "as left" error which shall be the average of the two elements. If a wide adjustment is necessary, recalibrate meter, as above.

If a meter is erratic at 10% load test, check at this load, with and without the register. Check and record the reading of the meter and also the maximum demand indicators, if connected. Check meter for starting load. Remove test leads, insert plugs in positions 1A and 1C, ensuring that they are tight, and remove plugs from positions 2A and 2C (see diagram of connections No. 2 attached). Replace test block cover, re-seal meter and test block cover, and leave supply in order.

(o) Limits of Error.

Meters shall be calibrated to a degree of accuracy as high as practicable. Meters must be calibrated to fall within the following limits of error:-

Load (Individual Elements)	Power Factor	% Limits of Error
At 10% Full Load	Unity	0.5 ±
At 200% " "	"	0.7 - to 1.0 +

Balance of Elements. The limits of error at light or full load tests between individual elements shall not be greater than 0.7%

(p) Recording of Test Results.

The arithmetical average of the two elements at each of the test loads shall be calculated, and this value only recorded on the Test Card.

(q) Calculation of Average Accuracy.

The average accuracy of a meter shall be calculated as set out in B.S.I. No. 1025, Meter Testing - Calculation of Meter Accuracy, using the average test results, as indicated in (p) above.

4. Testing Procedure - Current Transformer Meters.

(a) Checking Connections.

Except where stated below, check metering connections as set out in B.S.I. No. 1207, Meter Installation - Method of Checking Current Transformer Metering Connections. It should be noted, however, that the polyphase test block arrangement, as shown on the drawing attached to this Instruction, should be used in connection with B.S.I. No. 1207. Record results on Test Card, i.e. "Connections correct".

In the case of new installations, after checking connections, each element of the meter shall be checked for starting load only.

4. (a) Checking Connections (Cont'd.)

In periodic testing, where a Test Card indicates that the connections have been checked and are correct, it will not be necessary to re-check connections unless there is a doubt of the correctness of the connections, due to the meter test results or observations.

When testing current transformer meters as a result of a complaint, the metering connections must be checked, irrespective of whether they have been checked previously.

The terminal arrangement of the meter and test block, as shown on the drawing attached, should be noted particularly, as it is important that officers are familiar with the arrangement before proceeding to check metering connections or test the meter.

(b) Test Procedure.

Generally, meters shall be tested by testing each element separately, using the modified field testing equipment. Polyphase tests will only be carried out in certain specified instances. It is important that the three voltage coils be energised when the meter is being tested.

Before proceeding to test the meter, bridge the current transformers by inserting plugs at positions 2A, 2B and 2C. Remove plugs from positions 1A, 1B and 1C (see diagram of connections No. 3 attached).

To test the No. 1 or red phase element of the meter, connect the line or active load from the testing equipment at socket position 3A, the load lead at position 4A, and the neutral at position 6N. Join socket positions 7A and 5A by the lead provided for the purpose. This will connect an active supply to the testing equipment.

Nos. 2 & 3 phase elements shall be tested in a similar manner, using the appropriate plug socket position.

Note: At no time must the secondary of the current transformers be open circuited during testing operations.

(c) Creep.

Before connecting test equipment leads, and after having bridged the current transformers and removed the plugs from positions 1A, 1B and 1C, check the meter for creep. If the meter is found to be creeping either backward or forward, the time for one complete revolution of the meter disc shall be taken, and the kilowatthours due to the creep calculated and recorded, as set out in B.S.I. No. 603, Technical - Meter Testing Formulae.

(d) "As found" Tests.

"As found" tests shall be carried out in all cases and recorded, even though the meter may be found to be creeping. The "as found" tests shall be carried out before adjusting for creep.

(e) Starting Load.

Test for starting load which shall be not greater than 1.5% Full Load for each separate element. Note starting load for each element and record the average of the three elements.

4. (f) Light Load.

Test each element at 15% Full Load, Unity Power Factor, not less than two revolutions of the disc to be counted. Note "as found" errors and record the average error of the three elements, but make no adjustment. This test should indicate the condition of the meter bearings and register.

(g) Full Load - Unity Power Factor.

Test each element at 200% Full Load, Unity Power Factor, not less than ten revolutions of the disc to be counted. Note "as found" errors and record the average error of the three elements, but make no adjustment.

(h) Full Load - 0.5 Lag Power Factor.

Test each element at 200% Full Load, 0.5 lag power factor. Note errors and record the average error of the three elements, but make no adjustment.

When testing at 0.5 lag power factor, it is necessary to remove the 4-pin plug from the testing equipment, insert the 3-pin plug, and connect the lead attached to the 3-pin plug to the required leading phase.

Check with phase rotation indicator the direction of phase rotation from the voltage terminals at the polyphase test block or the meter terminals.

The rotation of the phases at the test block shall be taken as 1, 2, 3 from left to right, i.e. plug positions 7A, 7B and 7C. The leading phase required for 0.5 lag power factor shall be obtained as follows:-

Example 1: With phase rotation clockwise, and testing No. 1 or red phase element of the meter, 0.5 lag power factor is obtained by connecting the 3-pin plug to the potential socket 7B.

Example 2: With phase rotation anti-clockwise, and testing the No. 1 or red phase element of the meter, 0.5 lag power factor is obtained by connecting the 3-pin plug to the potential socket position 7C.

Note: It is important that the phase rotation in type SD meters is clockwise.

After having completed the "as found" tests, if the phase rotation is found to be anti-clockwise, it is necessary that it be made clockwise. This shall be carried out by the testing officer, if practicable. If not practicable, a report shall be forwarded to the supervisor who shall arrange for the Chief Installation Inspecto to correct the metering connections.

The meter shall not be recalibrated unless the rotation is clockwise.

4. (i) Recording of Test Results.

The errors recorded on the test card shall be equivalent polyphase errors. Due to interaction between elements these errors are more negative than the arithmetical average of the individual element errors at 200% F.L. U.P.F. and 0.5 lag P.F. to the extent of 1.2%.

The appropriate C.T. error shall be applied to each meter element error before calculating the arithmetical average errors of the three individual elements at each test load.

The interaction error of 1.2%– shall now be applied to the arithmetical average errors at 200% F.L. U.P.F. and 0.5 lag P.F. These resultant errors together with the arithmetical average error at 15% F.L. U.P.F. (these are the equivalent polyphase errors) shall be recorded on the test card.

The above method of determining the errors to be recorded applies to both "as found" and "as left" tests.

(j) Limits of "As found" Error for the Purpose of Recalibration.

Until further notice, meters tested in the field shall be recalibrated when the "as found" error of each element at any of the prescribed test loads exceeds 1.0%± after allowing for current transformer error and interaction error. Meters shall also be recalibrated if the errors for individual elements at any particular test load differ by more than 0.7%, or the difference between the 200% full load, unity power factor error and the 15% full load error exceeds 2.0%.

(k) Average Accuracy.

The average accuracy of a meter shall be calculated and recorded as set out in B.S.I. No. 1025, Meter Testing - Calculation of Meter Accuracy.

(l) Conditions under which Bearings shall be Changed.

Bearings of meters shall be changed in the following cases:-

(i) Where previous test results shown on the Test Card indicate that the bearings have not been changed during the previous two years.

(ii) Where the "as found" error at any of the test loads for each individual element is found to be in excess of 1.0%–, or the difference between the 200% Full Load error and the 15% Full Load error exceeds 2.0%.

(iii) The test results, when compared to previous test results shown on the Test Card, indicate an increasingly slow error at light load.

(m) Calibration.

(i) Adjust, if necessary, and calibrate meter by passing 200% Full Load current at Unity Power Factor through the No. 2 or yellow phase current element alone. Adjust within the limits of accuracy by the brake magnet. Calibrate the No. 1 or red phase element and the No. 3 or blue phase element in turn, by the

4. (m) (i) (Cont'd.).

balance adjustments, to approximate the error of the No. 2 or yellow phase element. When carrying out these checks, not less than 10 revolutions of the meter disc to be counted. Correct for current transformer and interaction errors.

(ii) Adjust, if necessary, and calibrate each element of the meter at 15% Full Load, Unity Power Factor.

(iii) If any adjustment is made, re-check each element at 200% Full Load and 0.5 lag power factor.

(n) Limits of Error.

The meter shall be recalibrated to a degree of accuracy as high as practicable.

Meters shall be calibrated to fall within the following limits of error, after allowing for current transformer error and interaction error.

Load (Individual Element)	Power Factor	% Limit of Error
At 15% Full Load	Unity	0.5 ±
At 200% " "	"	0.5 ±
At 200% " "	0.5 lag	0.5 ±

(o) Added Burden Test on Current Transformers.

An added burden test of the current transformers shall be carried out (for details of procedure for carrying out this test, see B.S.I. No. 1009, Meter Testing - Field Testing of Current Transformers - Added Burden Test).

(p) Reconnection.

Remove all test leads, insert plugs in positions 1A, 1B and 1C, ensuring that they are tight, and remove plugs from positions 2A, 2B and 2C. Check that meter is registering, and check and record readings. Re-seal and leave in order.

5. General Testing Procedure.

All meters shall be tested with cover on. When resetting register reading of meters, the dial pointers must be turned only by spinning the train, except where pointers are out of position.

6. Changing Meters.

Meters having defects such as defective terminals, defective register, defective coil, etc., are to be changed; also meters which may require considerable time in adjusting or removal of defects. The reason for changing meters must be stated on the Test Card, together with all particulars such as number, size and reading. The Test Card shall be attached to the meter removed.

In all cases where a meter is changed, each individual element of the replacement shall be checked for starting on load.

7. <u>Accuracy of Meters Queried by Customer.</u>

In cases where the customer queries the accuracy of his meter or meters and has lodged a test fee with the Council, the testing figures shall be forwarded to the supervisor for checking. Should such meters be found to be outside the limit of accuracy and it is possible to adjust the meter in the field, the adjustment shall be made. Should the meter be found to be outside the range of adjustment, it shall not be changed until such time as the dispute with the customer has been settled.

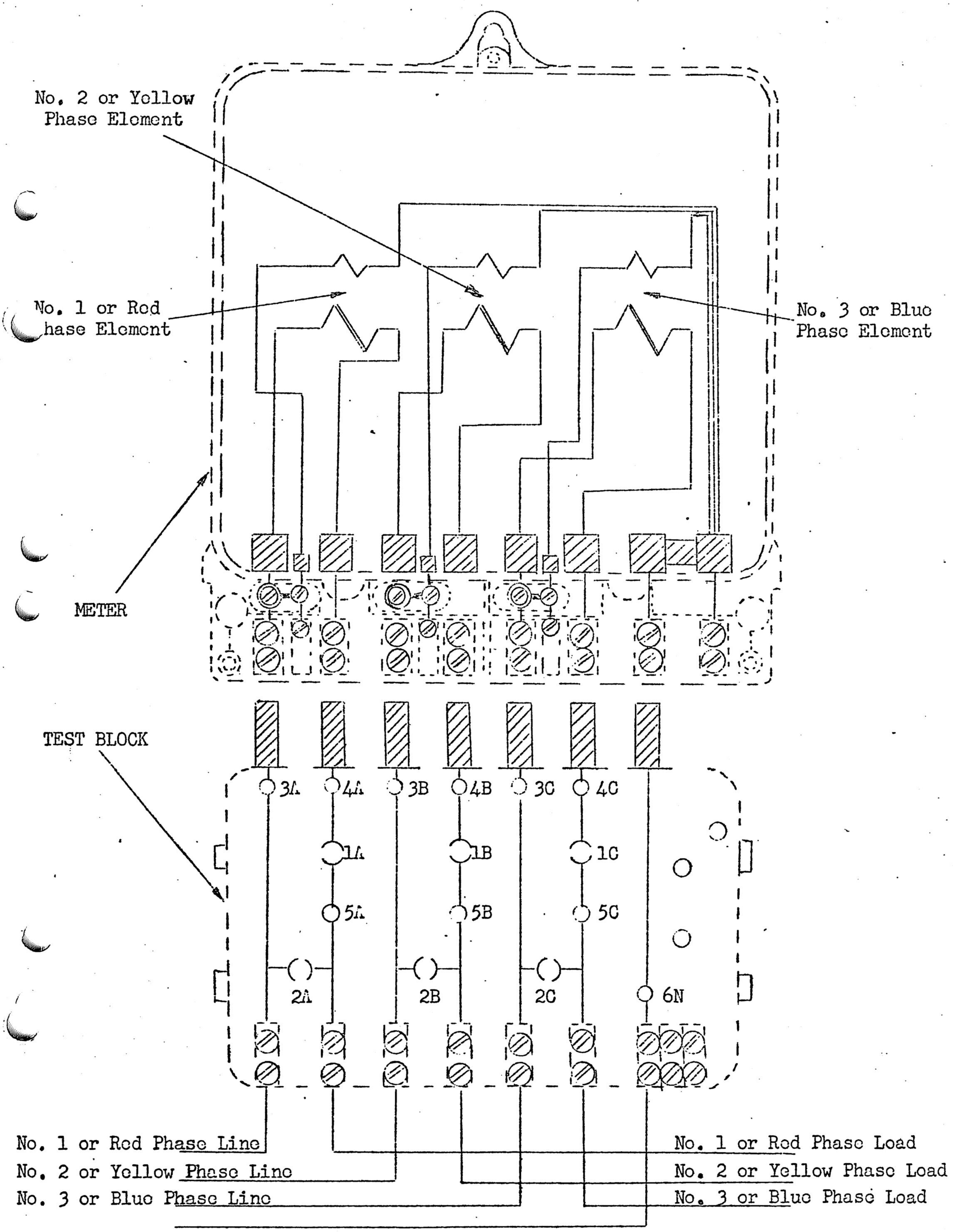
It should be noted particularly that where meters are found to be creeping, creep shall be measured and recorded and an "as found" test carried out before any adjustment is made for creep.

8. <u>Meters under Investigation.</u>

The procedure for dealing with meters under investigation is set out in B.S.I. No. 1851, Investigations - Energy Meters, Demand Meters and Time Switches. Meters under investigation shall not be tested or have the bearings replaced unless in accordance with the appropriate Instruction.

H. D. Muirhead
METER SUPERINTENDENT

<u>Attachment.</u>

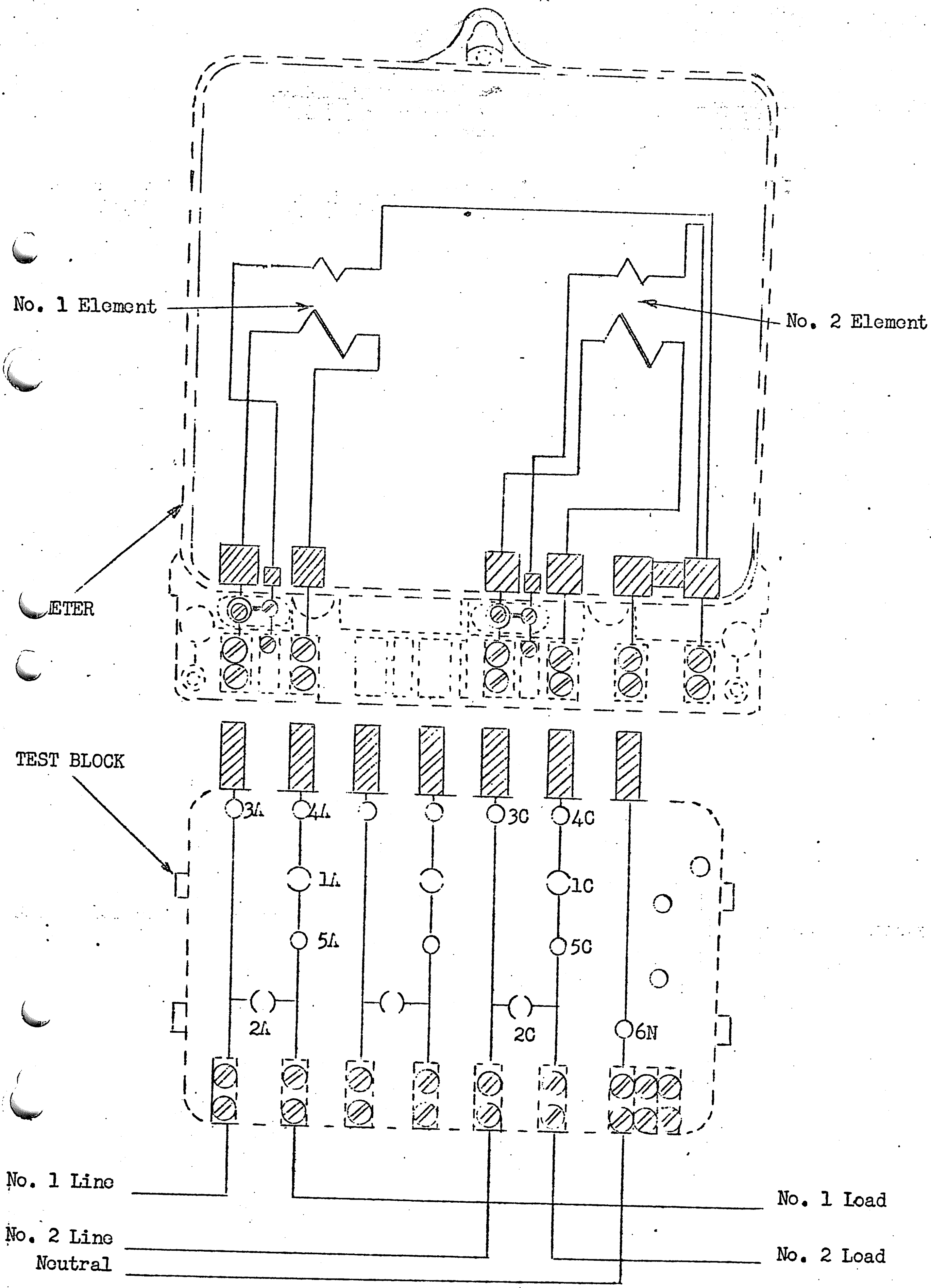


Front View of Test Block and Meter with Covers Removed.

DIAGRAM NO. 1

TERMINAL ARRANGEMENT AND CONNECTIONS OF DIRECT CONNECTED POLYPHASE TEST BLOCK AND TYPE SD 3-PHASE 4-WIRE WATTHOUR METER

Attachment to Branch Standing Instruction No. 1037, Meter Testing - Field Testing of Low Voltage Polyphase Watthour Meters, Type Emmco SD.

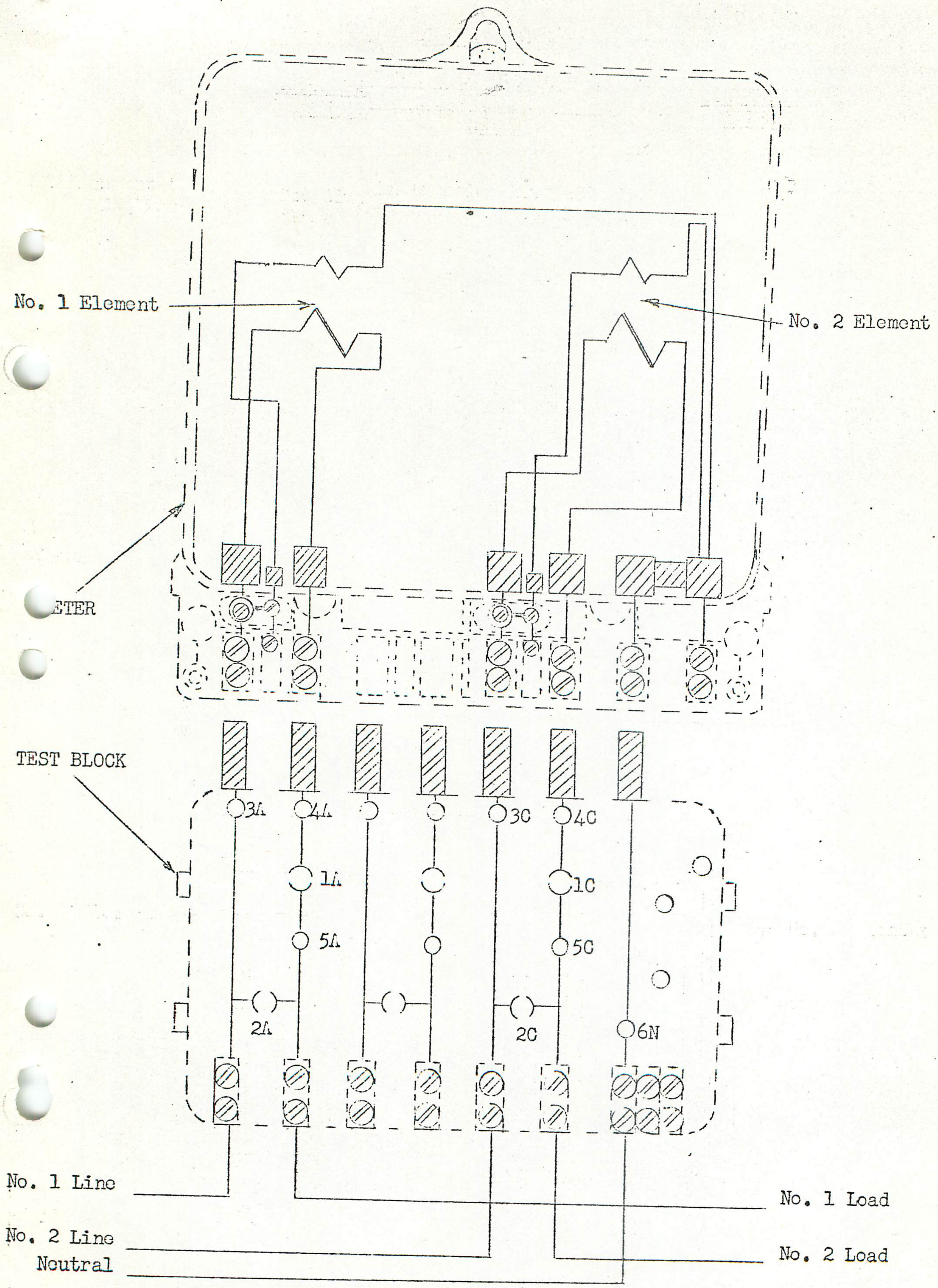


Front View of Test Block and Meter with Covers Removed.

DIAGRAM NO. 2

TERMINAL ARRANGEMENT AND CONNECTIONS OF DIRECT CONNECTED POLYPHASE TEST BLOCK AND TYPE SD 2-PHASE 3-WIRE WATTHOUR METER

Attachment to Branch Standing Instruction No. 1037, Meter Testing - Field Testing of Low Voltage Polyphase Watthour Meters, Type Emmco SD.



Front View of Test Block and Meter with Covers Removed.

DIAGRAM NO. 2

TERMINAL ARRANGEMENT AND CONNECTIONS OF DIRECT CONNECTED POLYPHASE TEST BLOCK AND TYPE SD 2-PHASE 3-WIRE WATTHOUR METER

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ATTACHMENT TO BRANCH STANDING INSTRUCTION NO. 1207.

THE CONVERSION AND USE OF THE L.V. POLYPHASE TEST EQUIPMENT AS AN "ON LOAD" CONNECTION CHECKER.

The relative phase angles between voltages and currents of a polyphase system may be determined by a test known as the "Woodson Check", in which the current of one phase is associated with the voltages of each of the three phases in turn. This test is repeated for the current of each of the other two phases providing a total of nine results. From the nine results (3 for each current) a vector diagram may be constructed showing the angular position of each phase current. As each phase current will generally have a component in phase with each of the three voltages, the angular position of the current producing these components is unique.

A test equipment comprising nine individual wattmetric elements would permit all measurements to be made simultaneously, however, satisfactory results may be obtained with three wattmetric elements and recording the three measurements associated with each phase, one phase at a time.

The polyphase test equipment comprises three rotary standard watthour meters and is, therefore, suitable for this purpose.

The equipment should be connected and used as follows:-

1. Remove the connection from the 5 amp. range terminal of each Rotating Standard Watthour Meter (Rotary).

2. Connect the Yellow current non-polarity output terminal to the 5 amp. range terminal of the Red Rotary.

3. Connect the Blue current non-polarity output terminal to the 5 amp. range terminal of the Yellow Rotary.

4. At the test block bridge all current transformers and open the movable links of Yellow and Blue phases.

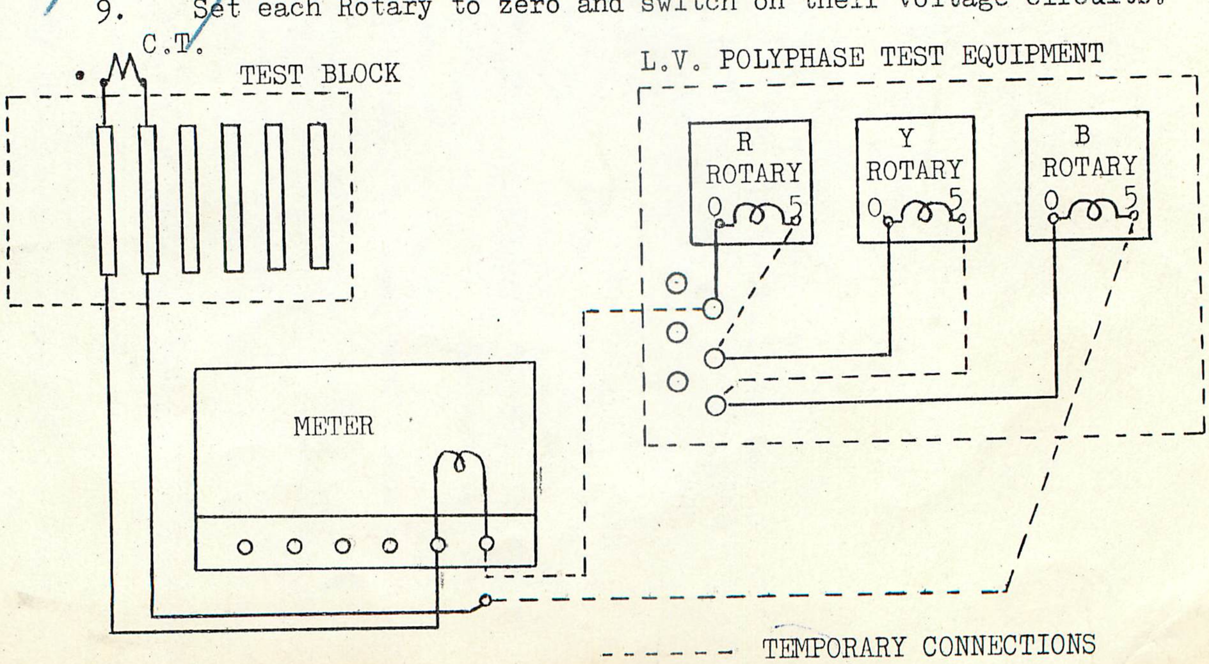
5. Withdraw the "Red" non-polarity wire from the meter and connect it to the 5 amp. range terminal of the Blue Rotary.

6. Connect the Red non-polarity meter terminal to the Red current non-polarity output terminal of the L.V. Polyphase Test Equipment.

7. Remove the bridge from the Red current links at the test block.

8. Put the P.F. Selector Switch of the L.V. Polyphase Test Equipment in the "Off" position and energise the Equipment (with three phases and neutral) from the test block or meter.

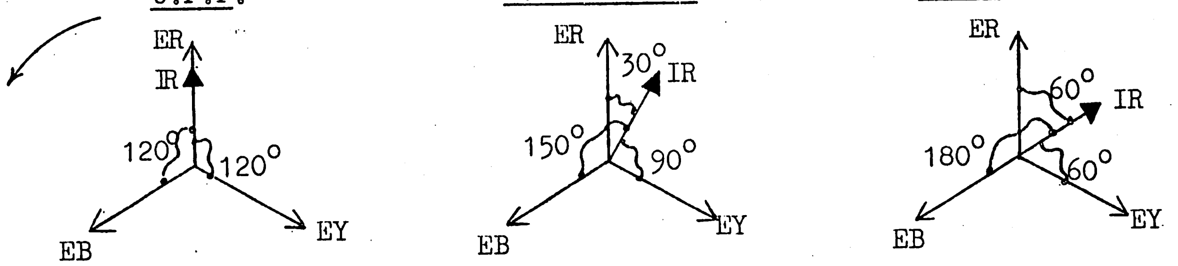
9. Set each Rotary to zero and switch on their voltage circuits.



The condition now is that the Red secondary current is passing through each Rotary current coil and is associated with Red, Yellow and Blue voltages respectively. The direction and comparative speed of rotation of the Rotary will depend on the phase angle of these associations, it being assumed that the phase voltages are equal and symmetrical.

Some vector representations for various conditions are shown:-

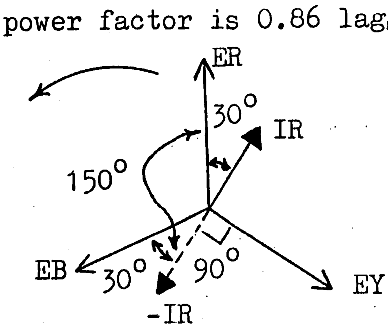
U.P.F. 0.86 LAG P.F. 0.5 LAG P.F.



The following tabulation shows the conditions for each Rotary at the various power factors illustrated.

P.F.	ROTARY	PHASE ANGLE, VOLTAGE AND CURRENT	COSINE & SUM OF R.Y.& B.	DIRECTION AND COMPARATIVE SPEED OF ROTATION.	
	Red	0	+1.0)	Forward	1.0
1.0	Yellow	120°	-0.5) = 0	Reverse	0.5
	Blue	120°	-0.5)	Reverse	0.5
	Red	30°	+0.86)	Forward	0.86
0.86 Lag	Yellow	90°	0) = 0	Stopped	0
	Blue	150°	-0.86)	Reverse	0.86
	Red	60°	+0.5)	Forward	0.5
0.5 Lag	Yellow	60°	+0.5) = 0	Forward	0.5
	Blue	180°	-1.0)	Reverse	1.0

The above analysis has shown the respective direction and comparative speed of rotation of each Rotary for known values of power factor. It has also shown that if connections are correct, the sum of the three Rotary readings is equal to zero. It does not prove, however, that the polarity of the current transformer used in the test (Red) is correct, for example assume that the Red current transformer polarity is incorrect and the load power factor is 0.86 lagging.



IR shown lagging ER by 30°.
-IR = IR reversed and leading ER by 150°.
The readings obtained would be:

Red Rotary	cos 150° = -0.86)	
Yellow Rotary	cos 90° = 0)	= 0
Blue Rotary	cos 30° = +0.86)	

When conducting a test of this nature, experience has shown that most satisfactory results can be achieved by switching the voltages on to the Rotaries and switching the voltages off when the most rapidly moving Rotary has completed approximately one half ($\frac{1}{2}$) of a revolution. The three readings are then taken and from these results the position of the current vector can be plotted. Bearing in mind that each Rotary rotates at a rate proportional to its voltage, current and the cosine of the angle between them, and further that since the current is common to each and voltages are assumed to be equal and symmetrical, the rate of rotation (the reading obtained) is proportional to the cosine or the in-phase component.

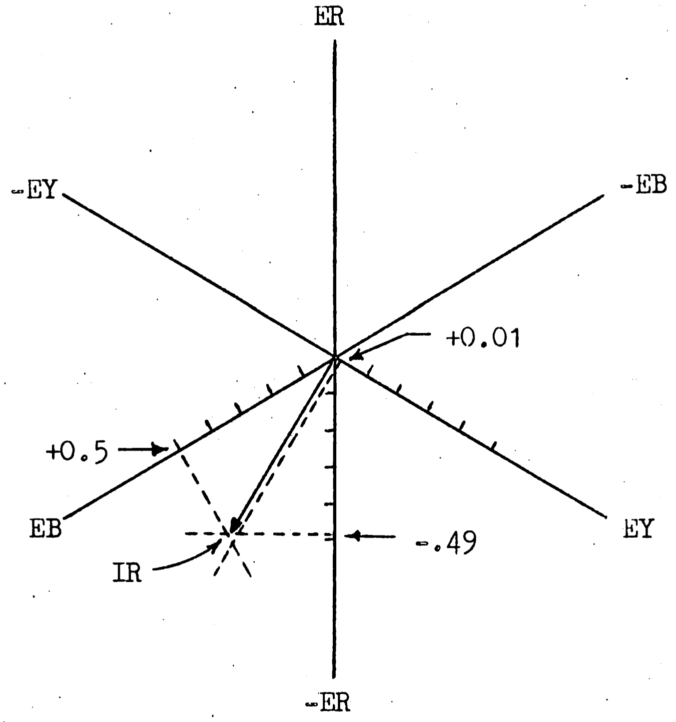
The direction of rotation of the meter under test should be observed; its direction should be the same as that of the Red Rotary.

In general the Red Rotary will always read positive for correct connection. The exception to this would be when a low power factor 415 volt load is connected. The effect of such a load is explained under "General".

Suppose the readings of the Rotaries were as follows:

Red	-0.49 revolutions
Yellow	+0.01 revolutions
Blue	+0.50 revolutions

Plot these values to scale on the appropriate voltage vectors and draw perpendiculars to them. The intersection of the three perpendiculars will give the locus of the current vector as illustrated.



This example indicates that IR leads ER by approximately 150° and that either the current transformer polarity was reversed, the association of voltage and current was incorrect, or the "connection checker" had been incorrectly connected into the circuit.

The angular position of Yellow and Blue currents can be determined repeating the procedure with the "connection checker" connected into Yellow and Blue secondary circuits at the meter. It is not necessary to alter any connections at the L.V. Polyphase Test Equipment for this purpose.

The direction of rotation of the meter should be observed; its direction should be the same as that of the Yellow or Blue Rotary dependent on the phase being investigated at the time.

When Yellow and Blue current vectors are plotted, it should be possible to determine whether, for example in the case of Red current leading by 150°, this is due to reversed polarity or incorrect association of current and voltage.

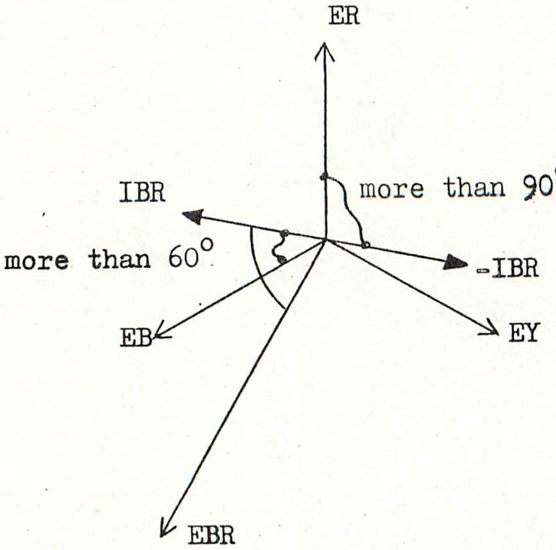
GENERAL.

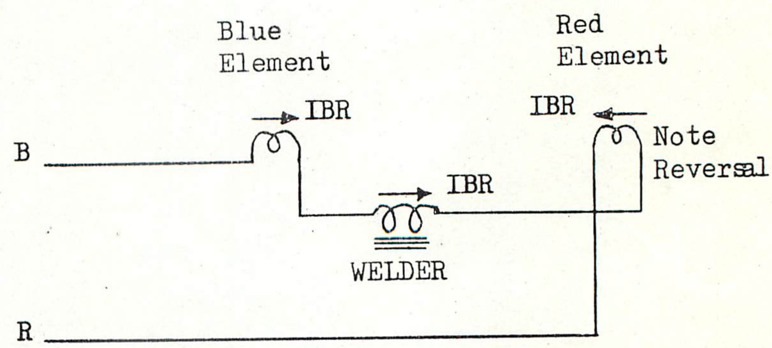
In some cases load may be connected between two phases and the current of such a load could lead or lag the line voltage by almost 90°. As the line voltage is displaced from the phase voltage by 30° the current seen by a particular meter element could be displaced from the voltage of that element by almost 120°.

Industrial and Commercial loads normally operate at lagging power factors. Capacitor load may cause an individual circuit to have a leading power factor but the Council's Service Rules do not permit a customer to operate with a leading power factor.

The type of load which may cause some concern to meter testing personnel is a low power factor 415V load such as electric welding equipment which, when idling, may have a power factor more lagging than 0.5. In large industrial complexes such types of load may be swamped by the general load, but in smaller installations the welding load may, at times, predominate and cause a reversal of one single phase meter or meter element.

In the following diagrams a single phase 415 volt welder is shown connected to Blue and Red phases.





As shown, the line current IBR lags the line voltage EBR by more than 60°. This condition could exist with the welder energised but idling. In the above case the Blue meter or element will see current IBR and voltage EB and will have forward torque.

The Red meter or element will see current -IBR and voltage ER and will have reverse torque because the related angle exceeds 90°.

BRANCH STANDING INSTRUCTION

/MER

SECTIONAL
(Procedure)

BRANCH METERING SERVICES SECTION

SUBJECT METER TESTING - INCORRECT CONNECTIONS.

OBJECTIVE To inform staff of the consequences of incorrect or unusual metering connections and of external conditions which may affect accuracy of registration.

MEANS OF ATTAINMENT.

1. SINGLE PHASE METERS.

1.1 Direct Connected Meters.

Modern single phase meters are of the three terminal type thus minimising the number of connections and terminals and reducing the possibility of incorrect connections. The three terminals known as Line, Neutral and Load from left to right are standard on all single phase meters used by the S.C.C.

Where four (4) terminals are provided the middle two are both neutral terminals; however, only one terminal shall be used. The preferred neutral terminal is that closest to the load terminal in order that the connection to the voltage coil is direct and not through a link which introduces two additional connections and associated resistances into the circuit.

Connections interchanged at the meter terminals will result in the following conditions:-

(a) Line and Load Interchanged.

The instantaneous direction of current flow in the current coil will be reversed to that in the voltage coil and the meter rotor will reverse. The voltage applied to the voltage coil will be the phase voltage minus the impedance voltage drop of the current coil.

(b) Line and Neutral Interchanged.

The voltage coil will be energised but the customer will not have an "active" connection and will therefore be without supply.

(c) Neutral and Load Interchanged.

The current coil of the meter will short circuit the supply voltage.

Four terminal meters have the disadvantage of a second neutral terminal as described above. If the line conductor is connected to it a short circuit will occur; if the load conductor is connected to it the customer will be without supply.

1.2 Transformer Connected Meters.

A transformer connected meter has its voltage and current coils each connected to two separate terminals and electrically isolated from each other.

Connections interchanged at the meter terminals will result in the following condition:-

(a) Voltage coil connections interchanged.

(b) Current coil connections interchanged.

Either (a) or (b) will result in reversal of the meter rotor. Reversal of both will result in normal rotation and correct registration.

(c) Voltage Connections Connected to the Current Coil.

This will result in a short circuit and should cause the voltage circuit fuse to rupture.

(d) One Voltage Coil Connection and One Current Coil Connection Interchanged.

The current transformer secondary winding meter current coil and voltage coil will be energised in series and it is unlikely that the small current which would circulate would produce sufficient torque for the rotor to start.

2. POLYPHASE METERS.

2.1 General.

The electromagnetic elements of single disc polyphase meters, being mounted in close proximity to each other are each influenced by magnetic coupling from the adjacent elements. Various compensation techniques are used to minimise this interference and compensation is usually effective for a particular phase rotation of the supply voltage. It is therefore necessary that polyphase meters are connected with the phase rotation for which they are calibrated.

2.2 Direct Connected Polyphase Meters.

The construction of a direct connected polyphase meter prevents the possibility of voltage coils and current coils of different phases being associated. Meters are provided with line and load terminals for each phase and one or two neutral terminals. In the Council only one neutral terminal is used and the same remarks as in (1) apply. Connections interchanged at the meter terminals will result in the following conditions:-

(a) Neutral and Load Interchanged.

Short circuit occurs through current coil.

(b) Neutral and Line Interchanged.

Phase to phase voltage applied on two potential coils. Nil supply on other phase.

(c) Line or Load of one Phase Interchanged with another Phase.

A short circuit will result.

(d) Line and Load of any one Phase Interchanged.

The incorrectly connected phase will produce a negative torque, this has to be compensated and with balanced load conditions will result in the torque produced by one phase cancelling the negative torque produced by the

(d) Line and Load of any one Phase Interchanged. (Cont'd).

incorrect phase. Thus, a two phase meter with balanced load would have no registration and a three phase meter would have 1/3 normal registration.

2.3 Polyphase - Transformer Connected Meters.

Separate voltage and current coil terminals are provided on these meters.

Interchange of line and load current coil connections will produce the results as in 2.2.

Polarity change of voltage coils can only occur if the neutral conductor is interchanged with an active connection.

In transformer connected meters colour coding is used to identify conductors and a step by step procedure to ensure correct association of voltage and current coils is essential.

The step by step procedure for ensuring correct connections is laid down in B.S.I. No. 1002.

3. EXTERNAL WIRING CONDITIONS WHICH MAY AFFECT METER ACCURACY.

3.1 Single Phase Service.

(a) Meter Neutral not Bonded to Service Neutral.

The meter will not register any load. Should this condition be encountered a permanent or temporary connection should be made, if practicable, and the details reported to the Supervisor.

(b) Active and Neutral Conductors Interchanged.

A fault or unauthorised load will not be registered, since the resultant currents do not flow through the current coil. Further, the "active" to general purpose outlets etc. will not be switched, resulting in a dangerous situation. Report the matter to your Supervisor.

3.2 Single Phase 415V Service.

Such a service may be provided for a single phase 415V load i.e. a welder service.

Correct metering would be provided with a single phase meter having a voltage coil rated at 415V however, supply could be taken from one phase to earth and be unmetered.

An alternative method is to use a 415 volt voltage coil and to divide the current coil into two halves, the connection of one half being reversed, and for the current of each of the two conductors to flow through one half of the current coil.

The most satisfactory metering is to install a neutral conductor and two single phase meters each connected one phase to neutral with 240 volt coils.

3.3 Two Phase 3 Wire Service

As in 3.2 the service would be metered with two single phase meters or a two phase 3 wire meter and when correctly connected will not be affected by external conditions.

3.4 Polyphase Service - 3 Phase 4 Wire.

Such a service may supply single or multiple metering installations using single or polyphase meters. With correct meter connections the only external wiring condition which may affect the metering accuracy is that of an open circuit neutral connection. The following remarks apply to all multiple meter installations whether meters used are single phase or polyphase.

(a) Installation practice is to connect each meter neutral connection direct to a neutral link on which is also connected the service neutral.

In large blocks of units multiple neutral links are required and practice is to ring the main neutral, looping from link to link. Occasionally loop connections have been omitted and it occurs that a number of meter neutrals may be bonded at the neutral link but not connected to the service neutral. If the meters are connected to the one phase open circuit voltage coils result but if the meters are connected to different phases a more interesting condition known as an "artificial"star results. If three voltage coils of identical impedance are connected between 3 phases with one end of each of the coils bonded together a star point is formed and as the impedance and resulting voltage drops of each coil are identical the star point can be shown to be at the centre of the impedance triangle and no voltage will exist between this artificial star point and earth i.e. neutral. Correct metering will result in this case but the condition is unsatisfactory for at some future date a meter may be added or removed thus destroying the balance.

Should only two meters be connected in this manner the line voltage (415V) will appear across the two coils in series thus each coil will have 207.5 volts applied instead of 240V. A further error will be introduced by the change in phase angle of the voltage coil current. Its' phase angle will not be that corresponding to the phase to which the meter is connected but that of the line voltage, i.e. a shift in phase by usually 30°.

An error will therefore be introduced into each meter and the meter will read

$$\frac{207.5}{240} \times 100 \times .866 = 75\% \text{ of its calibrated reading.}$$

Similarly errors will be introduced if more voltage coils are connected to one or two phases than to the other phase(s). The procedure for dealing with meters not connected to the service neutral is covered in an appendix to B.S.I. No. 1003.

(b) Polyphase Service - Customer Neutral not Direct from Neutral Service Link but Supplied Through Two or More Meter Neutral Links in Series

This condition may exist in some installations in older areas. Metering is correct, but the removal of a meter would break the customer's neutral and this could cause damage to the customer's appliances, as up to 415 volts may be impressed on a 240 volt appliance.

(b) (Cont'd).

If this condition is encountered during sample investigation or programmed testing, the meters shall not be tested. In the case of a meter query, the meters shall be tested with due precautions.

In any case do not change a meter but report the matter to the Supervisor who shall forward a report (MS.14) to the E.I.S. Branch for attention.

(c) Multiple Meter Installation - Short Circuit of Two Load Conductors on Different Phases.

This condition could be difficult to detect, particulary in regard to the identification of line and load conductors. Do not test the meters but report the matter to the Supervisor.

4. NUMBER OF METER ELEMENTS REQUIRED.

Blondel's Theorem - The theorem states:-

"In a system of N conductors, N-1 meter elements, properly connected, will measure the power or energy taken. The connection must be such that all potential coils have a common tie to the conductor in which there is no current coil".

This theorem is followed in practically all aspects of Council's metering installations.

In 3 phase 3 wire supplies, the system is known as the "2 wattmeter" method of power measurement and the proof of it correctly measuring the power or energy in a 3 phase 3 wire system is expounded in many Electrical Engineering texts. In the Council's system it is used for metering customers taking supply at high voltage where only a 3 wire system is used.

The 3 wire system is normally resultant upon the use of delta connected transformers, e.g. the 33kV windings of a power transformer may be star connected but the cable emanating from the star connection terminate on a transformer with a 33kV delta connected winding.

Thus only 3 conductors are involved though it is usual to earth the star or neutral point of the star connected winding. Current will only flow through this earth connection when one phase of the cable becomes damaged to earth and fault current return to the star point through the earth.

Should the cable be terminated on a transformer, also with a star winding with its neutral point earthed, it will be appreciated that the earth provides a fourth conductor and correct metering requires a three element meter.

The errors introduced in this case may be negligible and satisfactory accuracy may be achieved with a two element meter, however it must be ascertained that this is so.

The E.C. of N.S.W. has such a system and with high transmission voltages, 132kV and 330kV neutral current is found to exist and necessitates using 3 element meters. The currents are usually of 150Hz frequency, or higher, generated by the non linear magnetisation characteristics of the iron core of the transformer. With a delta winding a closed path exists within the transformer for such currents to circulate and therefore the currents do not exist in the lines to cause metering errors.

4. NUMBER OF METER ELEMENTS REQUIRED. (Cont'd).

Similarly with extra high voltage overhead transmission lines the capacity existing between each conductor and earth may be unbalanced and the out of balance capacitive current will flow in the earth, again introducing a four wire circuit.

Although capacitive current leads its own phase voltage by 90° and is therefore a quadrature component, which does not produce power, it will be appreciated that in the 2 wattmeter method the voltages applied to the metering elements are line voltages, already shifted by 30° such that a capacitive current will not be completely in quadrature with it.

5. TECHNICAL NOTES.

Further technical notes are attached to this Instruction as an Appendix.

6. AMENDMENT.

B.S.I. No. 1041, dated 6.11.47, has been amended to provide more general information for technical staff.

7. ISSUE.

Issue to: - Code A.T.,
S.I.C.

PRINCIPAL ENGINEER - METERING SERVICES.

CASE 1

Three Phase Installation - One Single Phase Meter on Each Phase - Voltage Coils Connected in Star but Not Connected to the Supply System Neutral.

When this condition exists, the algebraic sum of the three meter readings will be a true indication of the energy consumed only if the load produces no neutral current. Single phase loads or other loads producing current in the neutral will in general be incorrectly metered because in practice there will be some difference between the line to neutral voltages across the load terminals and the line to star point voltages across the meter voltage coils, even if the voltage coil impedances of the three meters are the same. This is due to asymmetry in the supply voltages inherent in a normal low voltage distribution system.

The differences in magnitude and relative phase angle of the voltages appearing across the meter voltage coils can become quite considerable if their impedances are not the same or if a time switch, volt meter, or other equipment is connected in parallel with one of them. The connection of a field test kit would lower the voltage on the phase to which it was connected to such an extent that the speed of rotation of the meter and rotary discs would be noticeably reduced.

Example.

To simplify the calculations, a symmetrical 240 volt supply will be assumed (Fig. 1.1).

Customer's load: 1 ampere per phase (Fig. 1.3) -

(a) at unity power factor,
(b) at 0.5 power factor lag.

Voltage across meter coils A, B and C - 215 volts, 215 volts, 305 volts (Fig. 1.2).

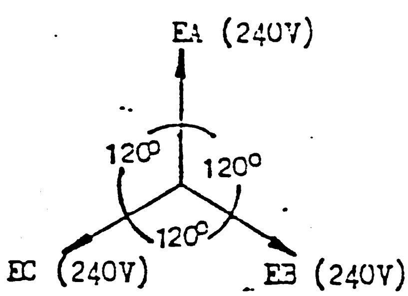


Fig. 1.1

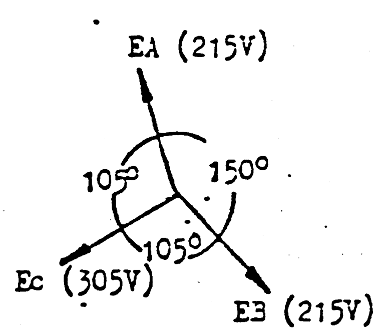


Fig. 1.2

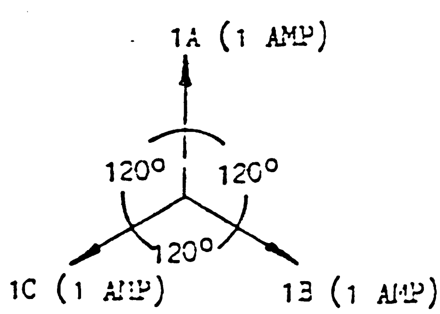


Fig. 1.3

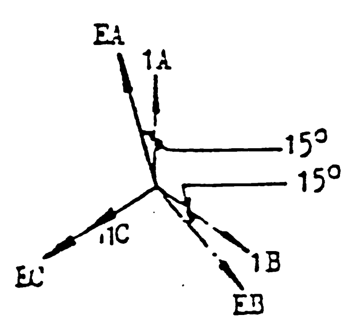


Fig. 1.4

	Load P.F.	Phase	Meter Load in Watts (EI cos Ø)		True Load Watts
	1.0	A	215 x 1 x cos 15° = 215 x 0.9659	= 207.5	240
(a)	1.0	B	215 x 1 x cos 15° = 215 x 0.9659	= 207.5	240
	1.0	C	305 x 1 x cos 0° = 305 x 1	= 305	240
			Total	720	720
	0.5 Lag.	A	215 x 1 x cos 75° = 215 x 0.2588	= 55.5	120
(b)	0.5 Lag.	B	215 x 1 x cos 45° = 215 x 0.7071	= 152	120
	0.5 Lag.	C	305 x 1 x cos 60° = 305 x 0.5	= 152.5	120
			Total	360	360

It can be shown that, with balanced load conditions but at power factors other than unity and 0.5 lag., the total registration would still be correct but, as can be seen, no meter correctly registers the single phase load connected to it. It is apparent also that, with voltage conditions as above, the meters would have a greater tendency to creep than is normal.

CASE 2

Polyphase Service - Three Single Phase Meters - Two Meters without System Neutral.

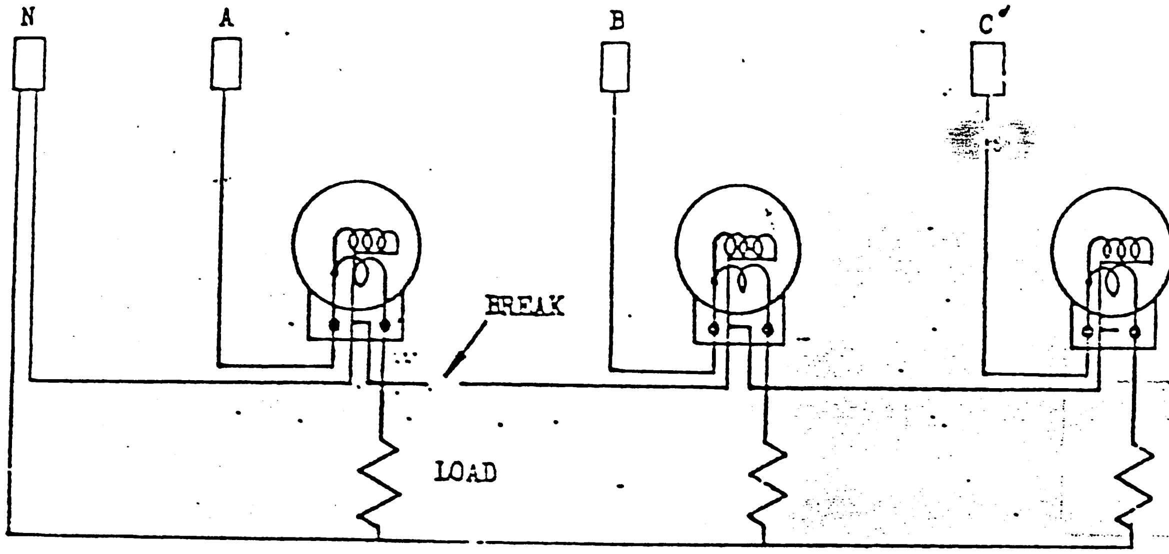
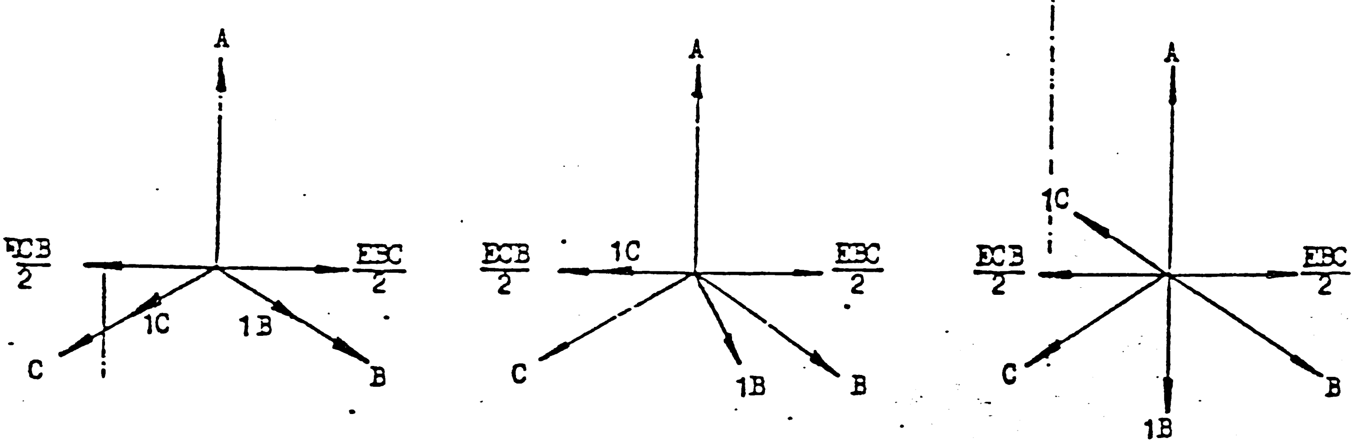


Fig. 2.1

The neutral to the meters on B and C phases is broken. Under these conditions the meter on A phase would register correctly, but the meters on B and C would generally register incorrectly.

It is assumed that the meters on B and C are of identical type, thus the voltage on each voltage coil would be half the line voltage.

The following vector diagrams are representative of conditions with U.P.F., 0.86 lag. P.F. and 0.5 lag. P.F. loads respectively.



U.P.F. 0.866 P.F. Lag. 0.5 P.F. Lag.

Fig. 2.2

The load as registered by each meter for each value of power factor is as follows, it being assumed that the current value in each case is 2 amperes and that the supply voltages are symmetrical.

Phase	Load P.F.	Meter Load Watts (EL cos Ø)	True Load Watts
C	1.0	$\frac{\sqrt{3} \times 240}{2} \times 2 \times \frac{\sqrt{3}}{2} = 360$	480
C	0.86 lag.	$\frac{\sqrt{3} \times 240}{2} \times 2 \times 1 = 416$	416
C	0.5 lag.	$\frac{\sqrt{3} \times 240}{2} \times 2 \times \frac{\sqrt{3}}{2} = 360$	240

Phase	Load P.F.	Meter Load Watts (EI cos Ø)	True Load Watts
B	1.0	$\frac{\sqrt{3} \times 240}{2} \times 2 \times \frac{\sqrt{3}}{2} = 360$	480
B	0.86 lag.	$\frac{\sqrt{3} \times 240}{2} \times 2 \times \frac{1}{2} = 208$	416
B	0.5 lag.	$\frac{\sqrt{3} \times 240}{2} \times 2 \times 0 = 0$	240

It will be noted that if the loads on B and C are equal and of the same power factor, the combined registration of the two meters is three quarters (75%) of the true load. If on the other hand a single phase 415 volt load is connected across B and C, it can be shown that it would be correctly metered.

CASE 3.

Single Phase Meter - Active and Neutral Conductors Interchanged and an Earth on the Customer's Installation.

This situation is rarely encountered, but has occurred, and a look at the factors involved provides a useful and interesting exercise.

An interchange of the active and neutral conductors could occur at the street pole or at the point of attachment and in itself would not cause incorrect meter registration.

If an earth fault occurred at point Z in Figure 3.1, it would cause fuses or circuit breakers to operate. However, consider an earth fault at Y.

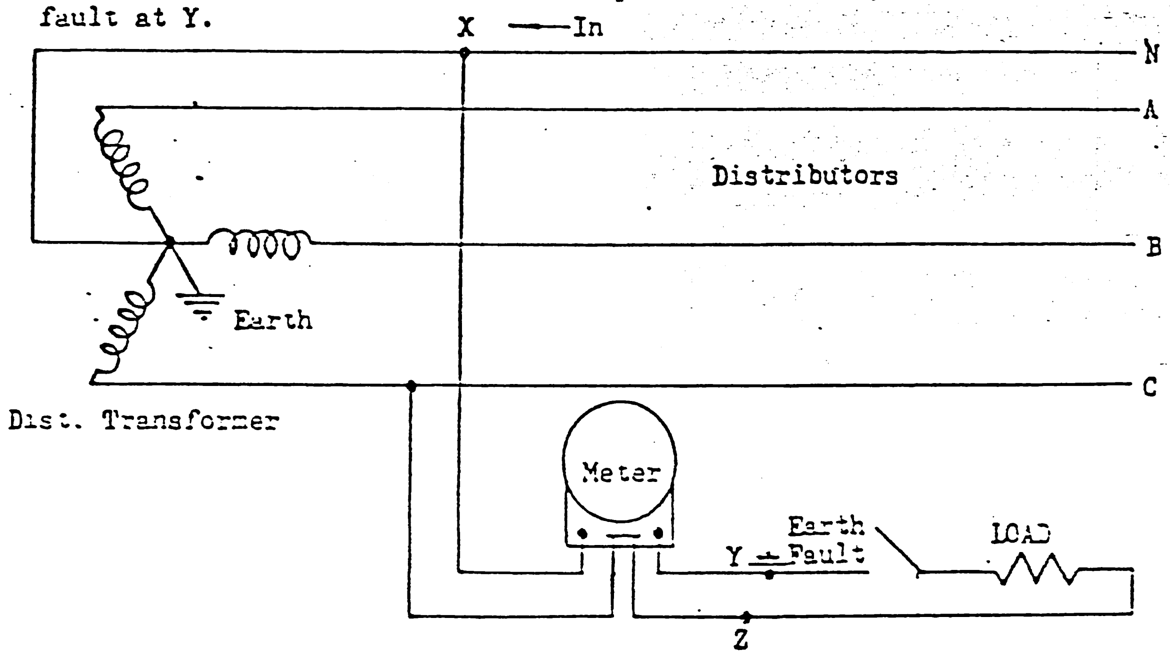


Fig. 3.1

In practice, street distributor neutral conductors may carry a considerable current. If it is assumed that the neutral current flows towards the earthed star point of the distribution transformer, then the voltage at point X will be higher than at the star point. Some neutral current will then flow from X to Y through the current coil of the meter to return to the transformer star point via the earthing system. The relative impedances of the two parallel current paths will determine the proportion of the neutral current flowing from X to Y.

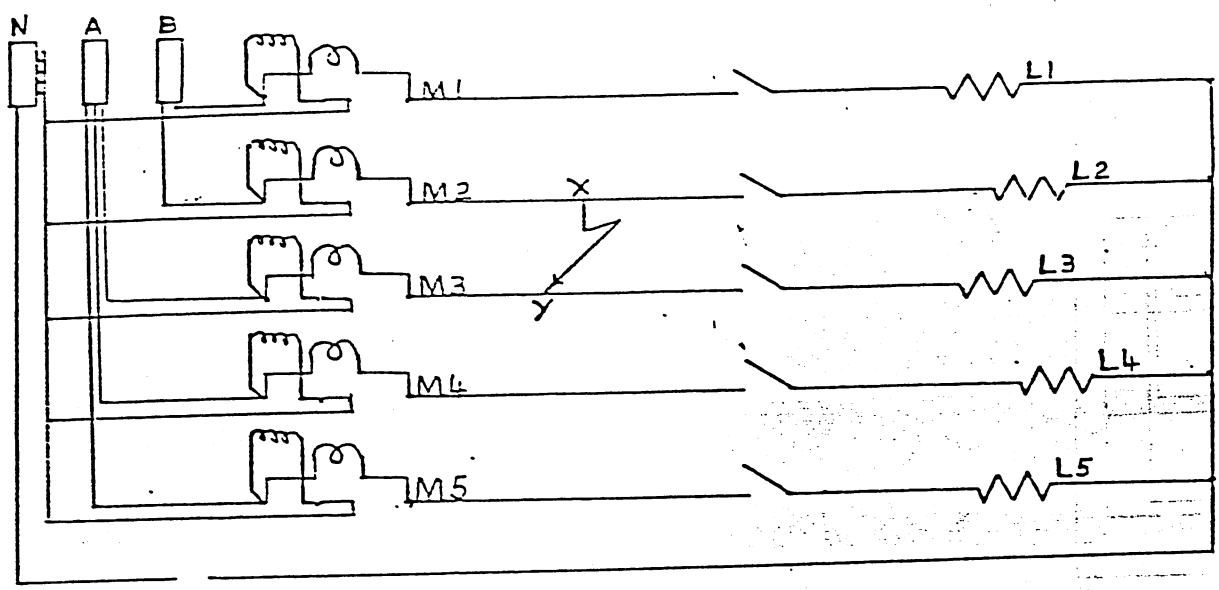
This current would tend to produce torque in the meter, dependent not only on the magnitude of the current but also on its phase relationship with the voltage on the voltage coil of the meter.

Since the neutral current is the reversed vector sum of the currents in the three phases, it can lead or lag any given reference point by up to 180°. Thus it may be in phase, 90° out of phase, or more than 90° out of phase with the voltage on the meter voltage coil. Under these conditions the meter disc may rotate in the forward direction, may stop or may rotate in the reverse direction, all in the space of seconds dependent on the neutral current variations.

It is apparent also that some of the customer's load current will bypass the meter current coil.

Multiple Meter Installation - Short Circuit of Two Load Conductors on Different Phases.

This situation is rare, but an examination of the possible effects is worthy of consideration. For example, consider five (5) separate single phase customers supplied from two (2) phases as shown. The customers are numbered from one to five.



If a short circuit occurred between X and Y (probably behind the meter board) then either one or both service cut outs could become open circuited. If both cut outs operated, no supply would be available. On the other hand, if only one cut out operated and the conductors at X and Y became and remained welded together, then a supply to all customers would still be available, but the metering would be seriously affected.

Assume then that A cut out only has operated and that X and Y are welded together, then -

Meter No. 1 would be unaffected;

Meter No. 2 would register the load of 2 + 3 + 4 + 5;

Meter No. 3 would register the load of 4 + 5, but in reverse;

Meter No. 4 would be unaffected;

Meter No. 5 would be unaffected.

A check of connections of meter No. 3 would appear to indicate that line and load had been interchanged at the meter, and in a known cas the Meter Branch officer concerned actually changed the two outer connections to the meter thinking that he had corrected a case of line and load cross. By so doing, he still left meter No. 2 registering the load of 2 + 3 + 4 + 5, but he had caused meter No. 3 to now register the load of 4 + 5 in a forward direction.

Assume now that B cut out only has operated and that X and Y are welded together, then -

Meter No. 1 would be unaffected;

Meter No. 2 would register the load of 1, but in reverse;

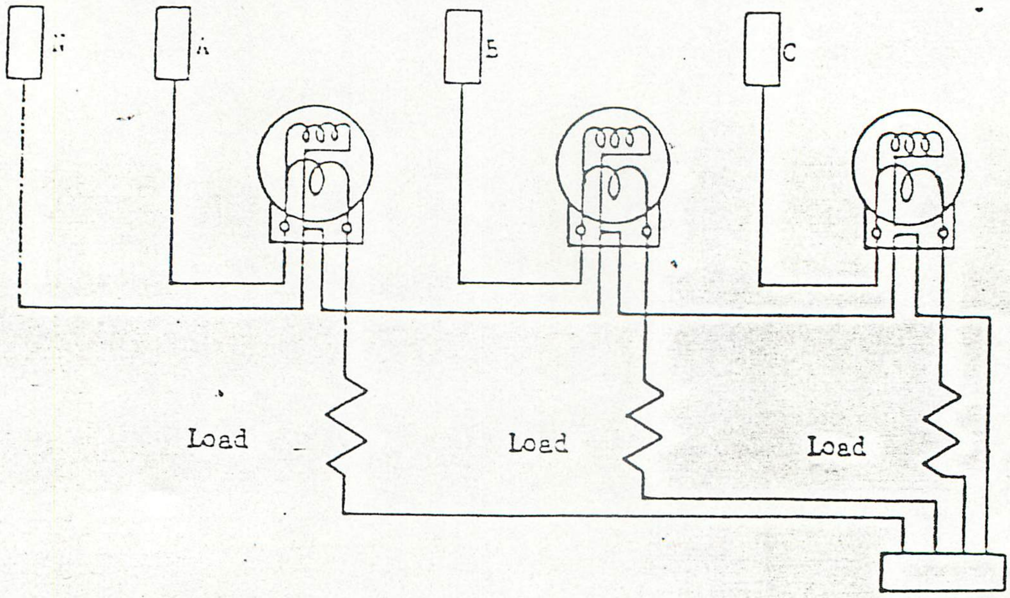
Meter No. 3 would register the load of 3 + 2 + 1;

Meter No. 4 would be unaffected;

Meter No. 5 would be unaffected.

CASE 5

Polyphase Service - Two or Three Single Phase Meter Neutral Links in Series with Customer's Neutral.



As will be seen from the diagram, the customer's neutral is supplied through the neutral link of each meter and the removal or any meter would break this neutral.

If the meter connected to A phase was removed and the customer happended to have equipment connected to B and C phases, then damage to the equipment could result. The likelihood or extent of damage would depend on the type of equipment connected at the time. Where the equipment consisted of a 60 watt lamp on each phase, then each lamp would have about half the 415 volts across it and no damage would result, but if the equipment on each phase was of different impedance, say an iron and a T.V. set, then the voltage across each equipment (being dependent on the relative impedances) would be high or low and damage could result. Under these circumstances the higher voltage may also damage the meter voltage coil to which it is applied.

APPENDIX

CASE 1

THREE PHASE INSTALLATION - ONE SINGLE PHASE METER ON EACH PHASE - VOLTAGE COILS CONNECTED IN STAR BUT NOT CONNECTED TO THE SUPPLY SYSTEM NEUTRAL

When this condition exists, the algebraic sum of the three meter readings will be a true indication of the energy consumed only if the load produces no neutral current. Single phase loads or other loads producing current in the neutral will, in general, be incorrectly metered because in practice, there will be some difference between the line to neutral voltages across the load terminals and the line to star point voltages across the meter voltage coils, even if the voltage coil impedances of the three meters are the same. This is due to asymmetry in the supply voltages inherent in a normal low voltage distribution system.

The differences in magnitude and relative phase angle of the voltages appearing across the meter voltage coils can become quite considerable if their impedances are not the same or if a time switch, volt meter, or other equipment is connected in parallel with one of them. The connection of a field test kit would lower the voltage on the phase to which it was connected to such an extent that the speed of rotation of the meter and rotary discs would be noticeably reduced.

Example

To simplify the calculations, a symmetrical 240 volt supply will be assumed (Fig. 1.1).

Customer's load: 1 ampere per phase (Fig. 1.3) -

(a) at unity power factor
(b) at 0.5 power factor lag.

Voltage across meter coils A, B and C - 215 volts, 215 volts, 305 volts (Fig. 1.2).

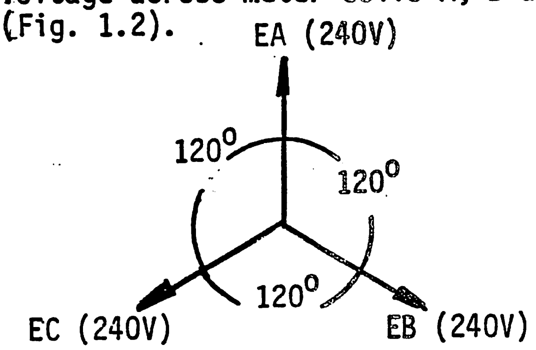


FIG. 1.1

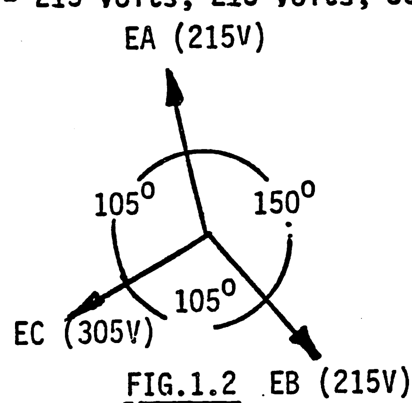


FIG.1.2

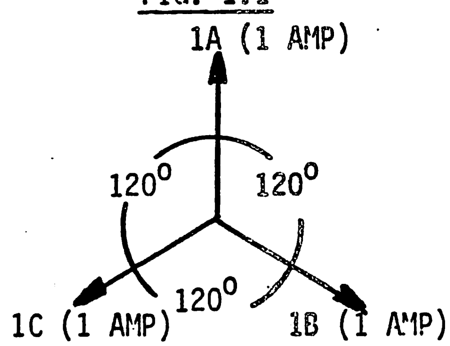


FIG. 1.3

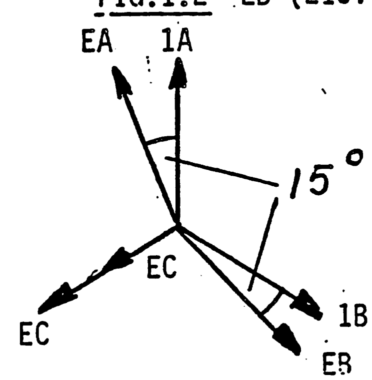


FIG. 1.4

	Load P.F.	Phase	Meter Load in Watts (EI cos Ø)	True Load Watts
	1.0	A	215 x 1 x cos 15^{o} = 215 x 0.9659 = 207.5	240
(a)	1.0	B	215 x 1 x cos 15^{o} = 215 x 0.9659 = 207.5	240
	1.0	C	305 x 1 x cos 0^{o} = 305 x 1 = 305	240
			Total 720	720
	0.5 Lag.	A	215 x 1 x cos 75^{o} = 215 x 0.2588 = 55.5	120
(b)	0.5 Lag.	B	215 x 1 x cos 45^{o} = 215 x 0.7071 = 152	120
	0.5 Lag.	C	305 x 1 x cos 60^{o} = 305 x 0.5 = 152.5	120
			Total 360	360

It can be shown that, with balanced load conditions but at power factors other than unity and 0.5 lag., the total registration would still be correct but, as can be seen, no meter correctly registers the single phase load connected to it. It is apparent also that, with voltage conditions as above, the meters would have a greater tendency to creep than is normal.

CASE 2

POLYPHASE SERVICE - THREE SINGLE PHASE METERS - TWO METERS WITHOUT SYSTEM NEUTRAL

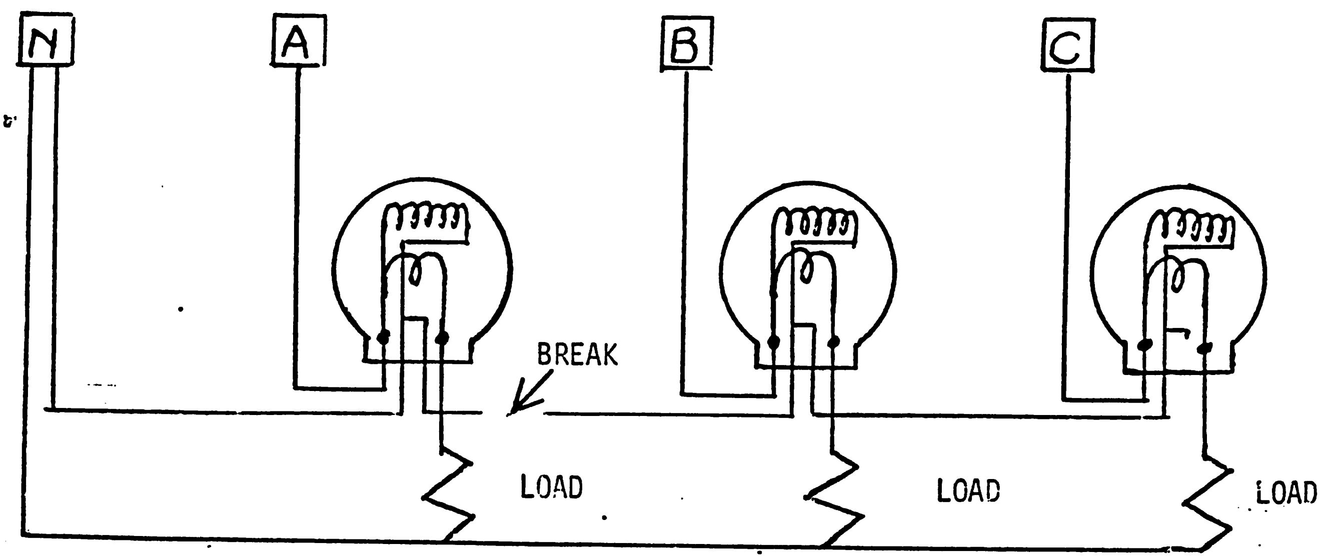


FIG. 2.1

The neutral to the meters on B and C phase is broken. Under these conditions, the meter on A phase would register correctly, but the meters on B and C would generally register incorrectly.

It is assumed that the meters on B and C are of identical type, thus the voltage on each voltage coil would be half the line voltage.

The following vector diagrams are representative of conditions with U.P.F., 0.86 lag. P.F. and 0.5 lag. P.F. loads respectively.

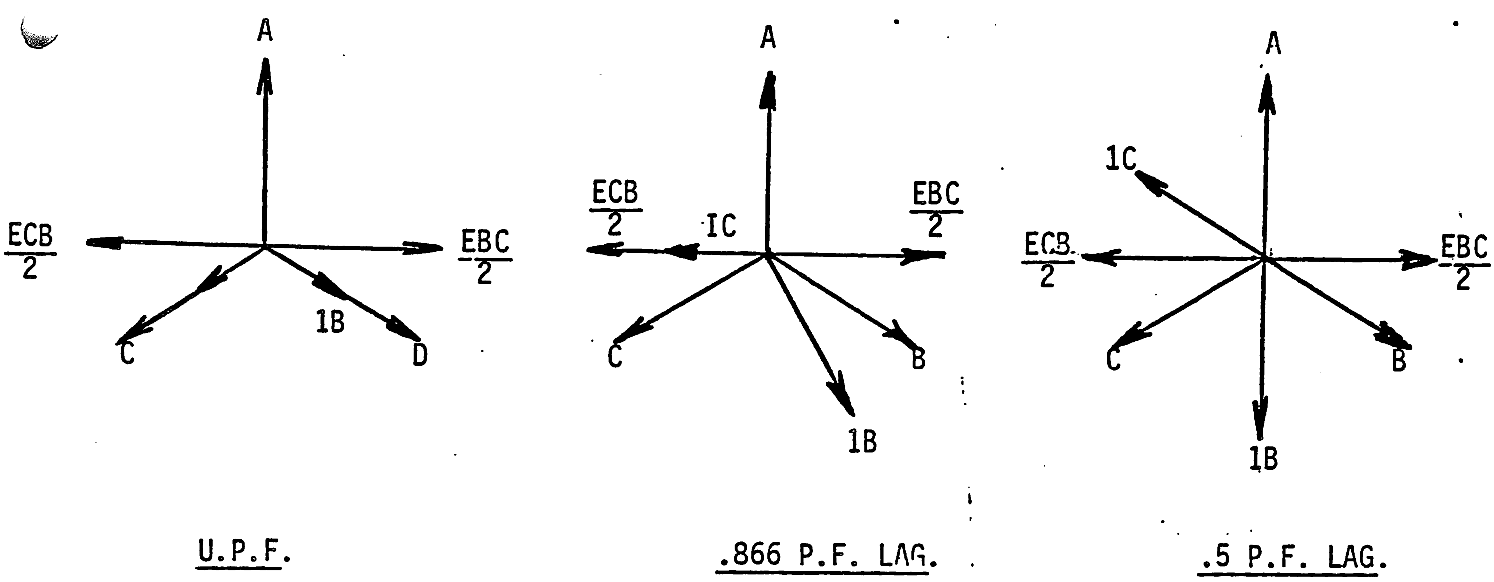


FIG. 2.2

The load as registered by each meter for each value of power factor is as follows, it being assumed that the current value in each case is 2 amperes and that the supply voltages are symmetrical.

Phase	Load P.F.	Meter Load Watts (EL cos ø)	True Load Watts
C	1.0	$\frac{\sqrt{3} \times 240}{2} \times 2 \times \frac{\sqrt{3}}{2} = 360$	480
C	0.86 lag.	$\frac{\sqrt{3} \times 240}{2} \times 2 \times 1 = 416$	416
C	0.5 lag.	$\frac{\sqrt{3} \times 240}{2} \times 2 \times \frac{\sqrt{3}}{2} = 360$	240
B	1.0	$\frac{\sqrt{3} \times 240}{2} \times 2 \times \frac{\sqrt{3}}{2} = 360$	480
B	0.86 lag.	$\frac{\sqrt{3} \times 240}{2} \times 2 \times \frac{1}{2} = 208$	416
B	0.5 lag.	$\frac{\sqrt{3} \times 240}{2} \times 2 \times 0 = 0$	240

It will be noted that if the loads on B and C are equal and of the same power factor, the combined registration of the two meters is three quarters (75%) of the true load. If on the other hand, a single phase 415 volt load is connected across B and C, it can be shown that it would be correctly metered.

CASE 3

SINGLE PHASE METER - ACTIVE AND NEUTRAL CONDUCTORS INTERCHANGED AND AN EARTH ON THE CUSTOMER'S INSTALLATION

This situation is rarely encountered, but has occurred, and a look at the factors involved provides a useful and interesting exercise.

An interchange of the active and neutral conductors could occur at the street pole or at the point of attachment and in itself, would not cause incorrect meter registration.

If an earth fault occurred at point Z in Figure 3.1, it would cause fuses or circuit breakers to operate. However, consider an earth fault at Y.

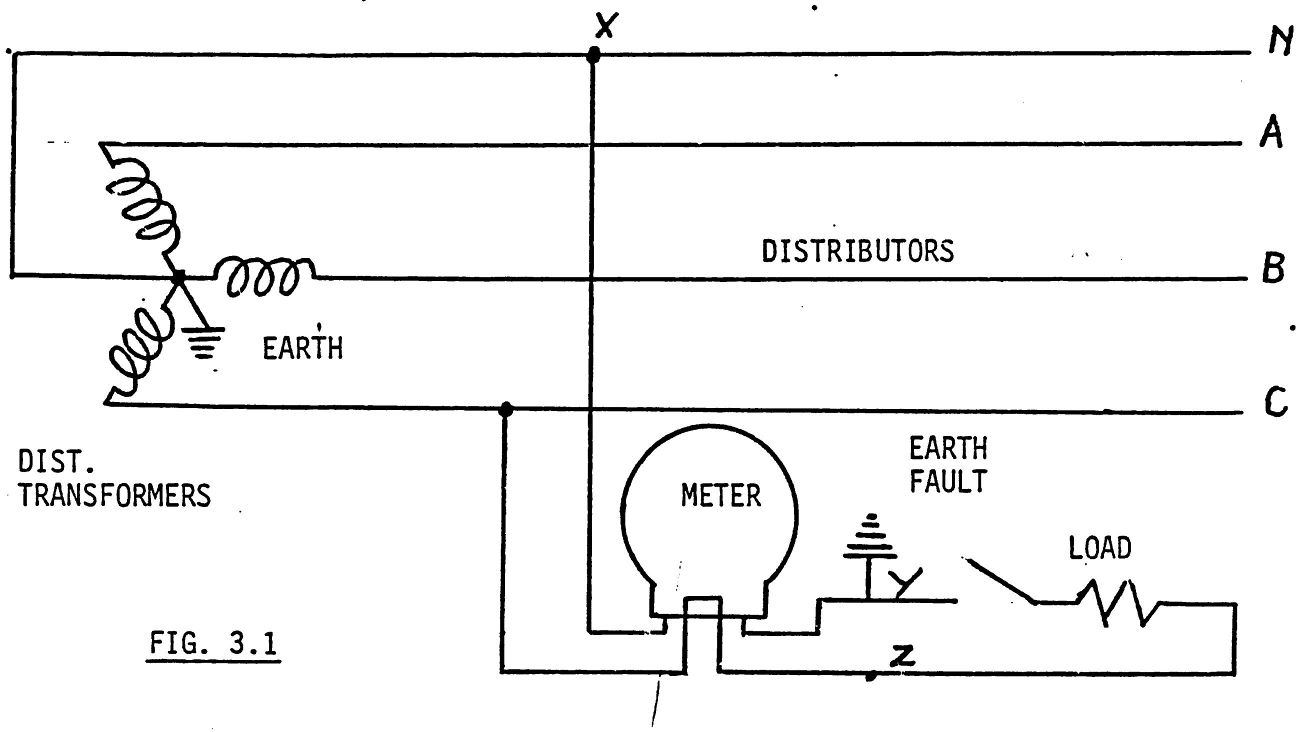


FIG. 3.1

In practice, street distributor neutral conductors may carry a considerable current. If it is assumed that the neutral current flows towards the earthed star point of the distribution transformer, then the voltage at point X will be higher than at the star point. Some neutral current will then flow from X to Y through the current coil of the meter to return to the transformer star point via the earthing system. The relative impedances of the two parallel current paths will determine the proportion of the neutral current flowing from X to Y.

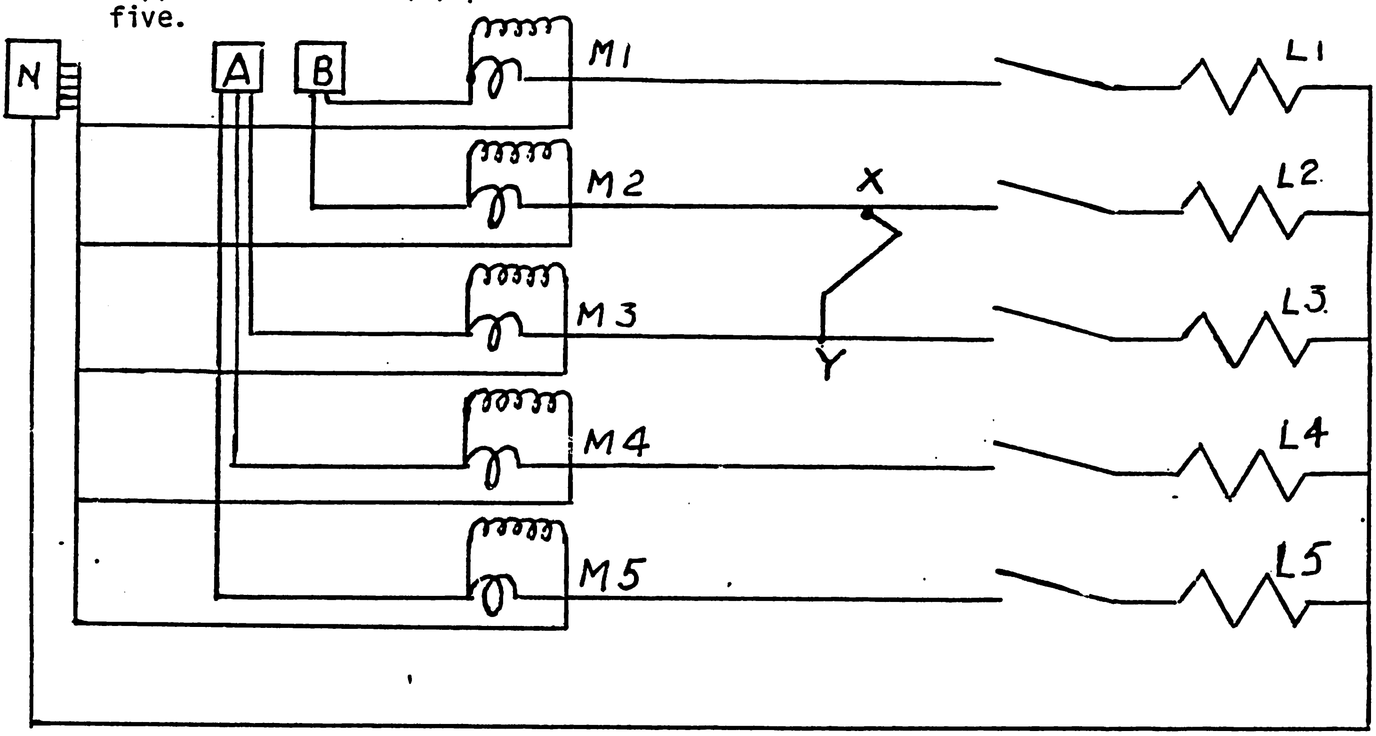
This current would tend to produce torque in the meter, dependent not only on the magnitude of the current but also on its phase relationship with the voltage on the voltage coil of the meter.

Since the neutral current is the reversed vector sum of the currents in the three phases, it can lead or lag any given reference point by up to 180°. Thus, it may be in phase, 90° out of phase, or more than 90° out of phase with the voltage on the meter voltage coil. Under these conditions, the meter disc may rotate in the forward direction, may stop or may rotate in the reverse direction, all in the space of seconds dependent on the neutral current variations.

It is apparent also that some of the customer's load current will bypass the meter current coil.

MULTIPLE METER INSTALLATION - SHORT CIRCUIT OF TWO LOAD CONDUCTORS ON DIFFERENT PHASES

This situation is rare, but an examination of the possible effects is worthy of consideration. For example, consider five (5) separate single phase customers supplied from two (2) phases as shown. The customers are numbered from one to five.



If a short circuit occurred between X and Y (probably behind the meter board), then either one or both service cut-outs could become open circuited. If both cut-outs operated, no supply would be available. On the other hand, if only one cut-out operated and the conductors at X and Y became and remained welded together, then a supply to all customers would still be available, but the metering would be seriously affected.

Assume then that A cut-out only has operated and that X and Y are welded together, then:-

Meter No. 1 would be unaffected;
Meter No. 2 would register the load of 2 + 3 + 4 + 5;
Meter No. 3 would register the load of 4 + 5, but in reverse;
Meter No. 4 would be unaffected;
Meter No. 5 would be unaffected.

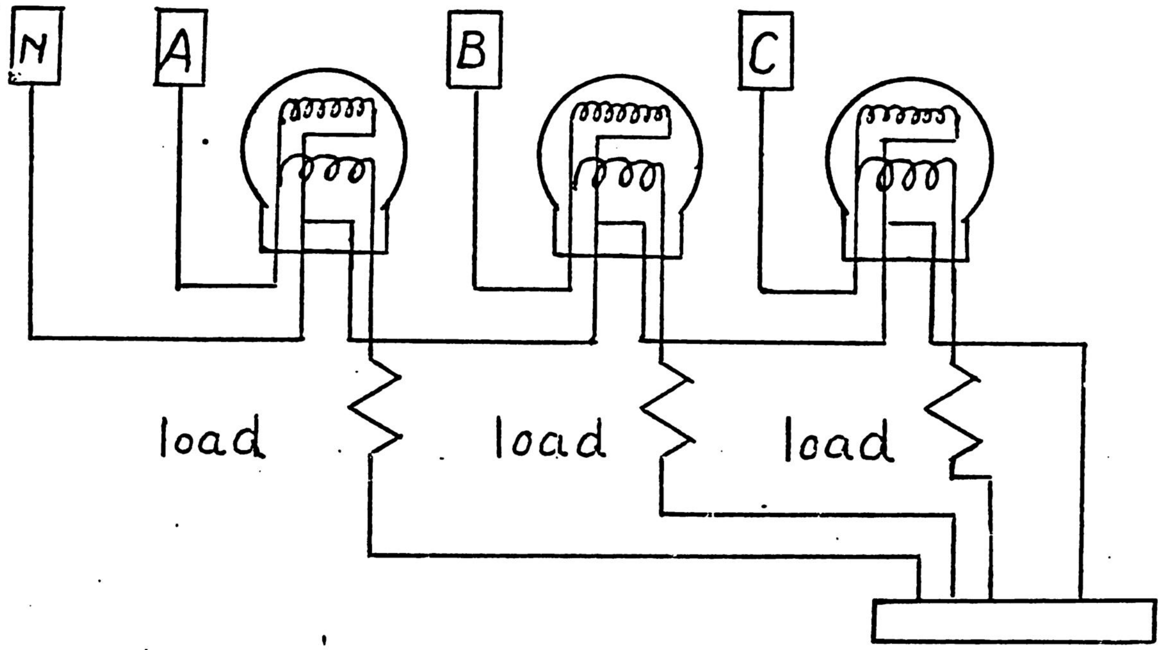
A check of connections of Meter No. 3 would appear to indicate that line and load had been interchanged at the meter, and in a known case, the Electrical Installations Branch officer concerned actually changed the two outer connections to the meter, thinking that he had corrected a case of line and load cross. By so doing, he still left Meter No. 2 registering the load of 2 + 3 + 4 + 5, but he had caused Meter No. 3 to now register the load of 4 + 5 in a forward direction.

Assume now that B cut-out only has operated and that X and Y are welded together, then:-

Meter No. 1 would be unaffected;
Meter No. 2 would register the load of 1, but in reverse;
Meter No. 3 would register the load of 3 + 2 + 1;
Meter No. 4 would be unaffected;
Meter No. 5 would be unaffected.

CASE 5

POLYPHASE SERVICE - TWO OR THREE SINGLE PHASE METER NEUTRAL LINKS IN SERIES WITH CUSTOMER'S NEUTRAL



As will be seen from the diagram, the customer's neutral is supplied through the neutral link of each meter and the removal or any meter would break this neutral.

If the meter connected to A phase was removed and the customer happened to have equipment connected to B and C phases, then damage to the equipment could result. The likelihood or extent of damage would depend on the type of equipment connected at the time. Where the equipment consisted of a 60 watt lamp on each phase, then each lamp would have about half the 415 volts across it and no damage would result, but if the equipment on each phase was of different impedance, say an iron and a T.V. set, then the voltage across each equipment (being dependent on the relative impedances) would be high or low and damage could result. Under these circumstances, the higher voltage may also damage the meter voltage coil to which it is applied.

2. <u>METER TESTING</u>

- Reporting of Test and Action To Be Taken
  - Excessive Accounts - A form M.S. 195 is to be completed and passed to the Supervisor for any test involving an excessive account

- Periodic and programmed Testing of Single Phase Direct Connected Meters
  - Check the position of the customer's main switches and note if in the 'OFF' position. Do not operate.
  - Check the meter number with that stated on the Meter Test Card.
  - Confirm that information recorded on test card is correct.
  - Place the ladder in a convenient position ensuring that the platform for the test kit is level.
  - If the meter has a metal case, check that the case is not 'alive' with test lamps. (All metal case meters other than 2 rate are obsolete and are to be changed).
  - Clean the meter and remove the terminal cover, recover the old seal.
  - Check that the active and neutral connections are correct with test lamps.
  - Connect bridging circuit and field test kit ensuring that the insulated tools specifically issued for this purpose are used and that your body is insulated or clear from earthed locations.
  - Test the meter for "Creep" by disconnecting the load circuit from the meter terminals and with voltage only applied to the meter observe that the Rotor does not continue to rotate for more than one revolution. Should the disc continue to creep, calculate the creep error. Adjust or change the meter.
  - Apply a load of 1A at unity power factor, to the meter, and determine the meter error for a minimum of 2 disc revolutions and record the "as found" error.
  - Apply a load of 20A at unity power factor, to the meter, and determine the meter error for a minimum of 10 disc revolutions, or such additional number of disc revolutions as may be required to ensure that at least 5 revolutions of the rotary take place, and record the "as found" error.
  - Where the test is for a Treasury or Customer Query and the "as found" tests are completed, carefully remove the meter cover and prove with test lamps that the grid is not alive, then inspect for obstruction, rust, dirt or moisture, meshing of register, loose pointers, etc.
  - Check the results against the limits shown on p.6.1. which will determine if the meter is to be changed, adjusted or left "as found". Where no adjustments are carried out, the "as left" figures will be recorded as for the "as found".
  - Remove test kit and replace any connections which were removed, check all screws for tightness, replace covers and reseal. Work on and complete one meter at a time to prevent interchange of parts when testing several meters at the one premises.
  - For Treasury and Customer queries only prove the register ratio by passing sufficient load current through the meter to cause registration of one or more dial divisions and comparing it with a calculated input.
  - Also on Treasury and Customer queries and the service is polyphase with more than one single phase meter, prove that the meter neutrals are bonded to the main neutral. See p.6.1.05 for procedure of this test.

AMENDMENTS

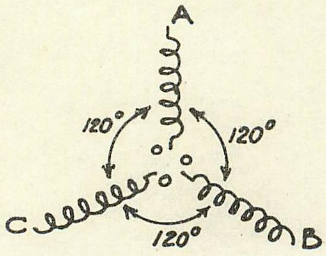


FIG 1

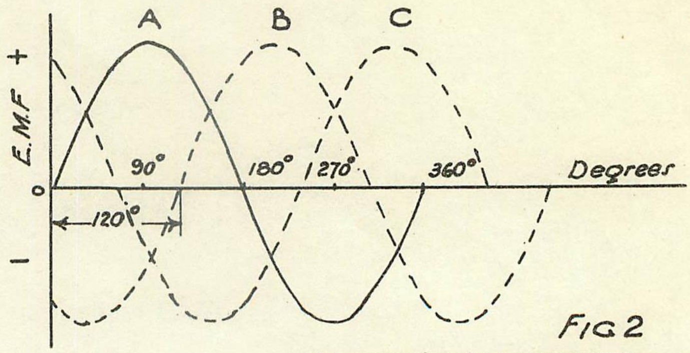


FIG 2

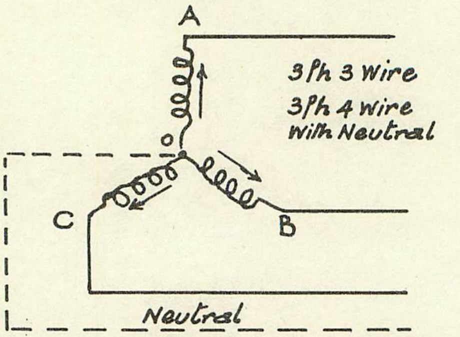


FIG 3 - ⅄ STAR CONNECTION

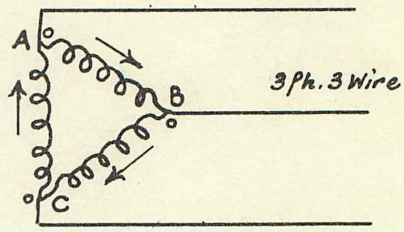


FIG 4 DELTA Δ CONNECTION

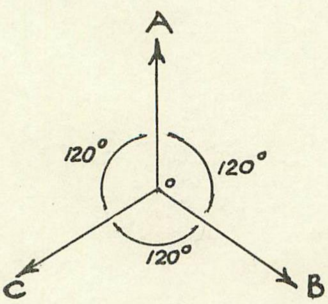


FIG 5

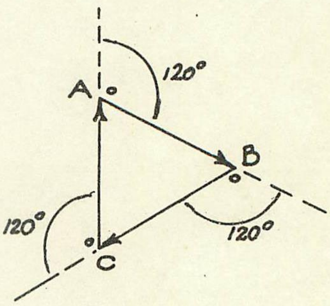


FIG 6

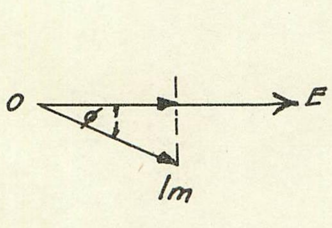


FIG 7

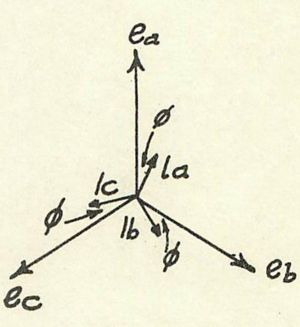


FIG 8

DRAWN		SUP. E.E.	
TRACED	F.S.D.	M.S.	
CHECKED	E.R.C. 2/4/40	A.CON. E.	
S.D.		CON. E.	
		CH. E.	

THE SYDNEY COUNTY COUNCIL

POLYPHASE METERING DIAGRAMS

STAND. INSTRUCTIONS Nº 18

SHEET Nº 1

SCALE

DATE 1 · 4 · 40

D11145E

D11145E

6. CALIBRATION OF LANDIS & GYR WATTHOUR METER - TYPE 3-PHASE, 2-ELEMENT, SERIES "F"

(Reference:- Landis & Gyr's Instruction Manual A1 04 23 E.2.38)

The following Instruction covers Calibration Procedure as distinct from Testing Procedure. Meters received from manufacturers are calibrated prior to shipment and should, in the first instance, be tested only.

NOTE: A separate Instruction will be issued for this form of testing, the results of which will determine:-

(a) if the accuracy as found is satisfactory,

(b) if certain minor adjustments can be made to obtain an acceptable accuracy curve without re-calibration,

(c) if the meter should be re-calibrated.

The numbers in brackets () refer to the adjustments indicated in Figure 1, Page of this Instruction. The rotor, register and top brake magnets are not shown in the photograph in order to facilitate identification of the various adjustments.

When in position these top element magnets are fixed and no adjusting screw is provided - all full load non-inductive calibration being made on the bottom element adjustment (5). A change in the position of either set of brake magnets affects both elements alike.

6.1 Preparing for Calibration

(a) Connect the meter to the voltage and current circuits of the bench supply in accordance with the diagram of connections mounted inside the terminal cover. Disconnect the internal voltage and current circuits of the meter from one another by opening any links provided in the terminal block.

(b) The voltage coils should be energised at rated voltage for at least half an hour to warm up. During this time the meter is to be examined as to its mechanical condition, dust removed from the air gaps, the bearings set, etc., and the register removed and examined. In refixing make sure that there is sufficient play between the rotor shaft and register worm wheel to prevent sticking or slipping.

6.2 Low Load Adjustment

(a) The low load adjustment is performed with vanes (1). Firstly, set these to an angle of approximately 30 degrees to the voltage core. Movement of the left hand vane towards

the rotor disc increases the forward torque; movement of the right hand vane in the same direction produces a reduction of net forward torque.

(b) It is preferable to use the right hand vane, as this provides a more sensitive adjustment. The left hand vane should only be used when the requisite torque cannot otherwise be obtained; i.e., when the right hand vane is in the extreme position.

(c) The adjustment of the vanes is correct when the rotor has a small amount of forward creep at rated voltage, the current coils not being excited (no load torque). This creep should be distributed as evenly as possible between the driving elements. For this purpose voltage should be applied to each element separately.

6.3 Preliminary Anti-creep Setting

The anti-creep wire mounted on the rotor spindle should be adjusted in relationship to the iron tongue on the voltage core (7) so that in spite of the no-load torque (see paragraph 6.2) the rotor cannot make a complete revolution on voltages within limits of ± 20% of rating, the current coils being de-energised. It is advisable to set the anti-creep wire so that when the meter reaches its stopping point the mark on the rotor disc is visible through the window in the cover.

6.4 Balancing of Torques

(a) Firstly, the voltage coils of the upper and lower driving elements should be connected to the same source of voltage, and the corresponding current coils should be so connected in series with one another that the two driving elements produce opposing torques.

(b) The wattmeter used, should operate on the same voltage and carry the same current as the meter itself. Full rated load at unity power factor is applied and the current cores adjusted with the aid of screws (2) so as to bring the rotor to a standstill. The torques produced by the two driving elements are now of equal magnitude.

(c) To ensure that the current cores will remain parallel to the rotor disc during this adjustment, the two adjusting screws (2) of each element must always be turned to the same extent, but in opposite directions. Small plates (6) attached to the meter frame, indicates the direction of movement required to increase or decrease the torque, the indication consisting of an arrow, a "+" and a "-" sign for increase and decrease respectively.

(d) When the driving elements of the meter have been balanced the adjusting screws (2) should be slacked off by a slight reverse movement.

(e) While carrying out these operations, make sure that the anti-creep wire is not near enough to the iron tongue to be affected by the latter.

(f) Re-check preliminary low load adjustment - and adjust right hand vane(s) (1) if necessary.

6.5 Quadrature Adjustment

(a) Rated voltage and rated current at element zero power factor should now be applied to each driving element in turn, the connections being such as to give the normal direction of rotation.

(b) The in-phase power is now zero and the rotor should therefore remain stationary. If this is not the case the twin copper vanes (3) should be adjusted to give zero rotor speed (with the slight tendency to creep which has already been set). Movement of the copper vanes into the air gaps of the magnetic circuit reduced the torque in the normal direction of rotation; moving them further out has the opposite effect.

6.6 Fine Balancing of Torques

It is now necessary to measure the speed of the rotor with the driving elements successively energised at rated load and unity power factor. By careful adjustment of the one or the other current core screws (2) any slight differences of speed as between the different driving elements may be corrected.

6.7 Setting the Speed at Rated Load

Both elements should now be energised at rated voltage, rated current and unity power factor. The speed is set in accordance with the constant appearing on the nameplate, brake magnets (4) being adjusted by means of micrometer screw (5) for this purpose. Very slight discrepancies may be expected between unbalanced and balanced loads, the tendency being towards a negative error on balanced loads. By rotating the micrometer screw in a clockwise direction the rotor speed may be increased and vice-versa. The fixing screws of the magnet carrier should be slightly slackened before adjustment is made, and subsequently re-tightened. It is inadvisable to alter the settings of the magnets themselves.

6.8 Low Load Test

The meter should be loaded at ten percent, of rated load and unity power factor on both driving elements and the resulting speed checked. A similar test should be carried out at five percent of rated load. Any correction of the speeds should be made with the aid of the low load vanes (1).

6.9 Checking

The driving elements should be checked separately at 100 percent rated current and 0.5 power factor lag, and at ten percent rated current and unity power factor. Provided the adjustments described above have been carefully carried out there will now be no serious error in the rotor speed. If necessary the adjustments may be slightly reset to suit.

6.10 Three-Phase Tests

Three-phase tests should now be carried out at 100 percent and 50 percent load unity power factor .866 and .5 power factor lag and at 10 percent load unity p.f. and .866 power factor lag.

6.11 Starting Check

Kilowatthour meters of the F-series should start and continue to rotate at 0.4 percent of rated load. At zero load, on the other hand, they should show no continuous creep at rated voltage $\pm$ 20%. Any adjustment which may be required at this stage should be made by resetting the anti-creep wire in relation to the iron tongue (7).

6.12 Full Load Dial Test

Full load dial test is desirable to check register gearing.

6.13 Insulation Test

After calibration the meters should be subjected to an insulation test at 1000 Volts. This should be applied between the current and voltage circuits and the case; and between current circuits and voltage circuits. It is advisable to repeat this test each time the meter is recalibrated.

When the insulation test has been completed any links disconnected in the terminal block should be reconnected, the meter closed, and if necessary, sealed.

When testing polyphase meters (including SD Sangamo etc.) the error of each load (200% & 10%) is taken on each of the three phases (or two if applicable) and these are added then divided by the number of phases. Thus if a S.D 10/60 was found to have the following errors at 200% rated or basic load UPF (Commercial)

Phase A. 3.1 +
Phase B 2.5 +
Phase C. 1.6 −

$= 3.1\%+ \; + \; 2.5\%+ \; + \; 1.6\%-$

$= \frac{4\%+}{3} = 1.3\%+$

and at 200% basic 0.5 lag the results were

Phase A. 2.1+
" B. 3.0+
" C. 3.0−

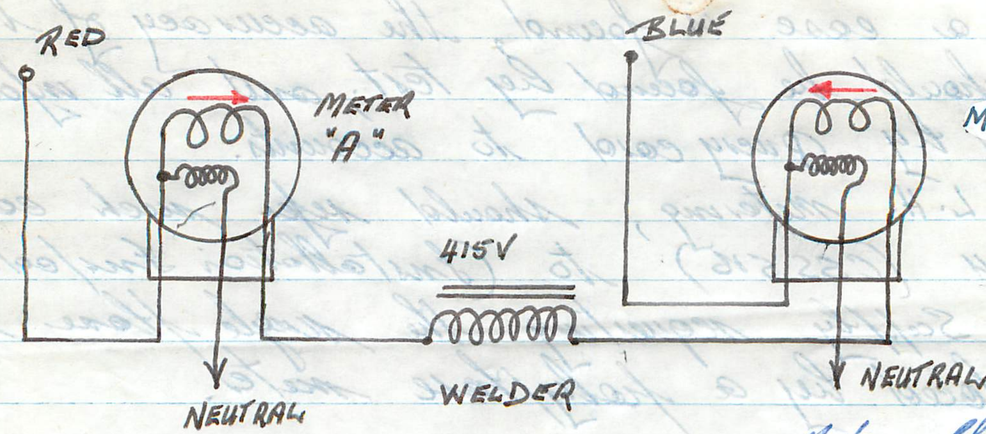
$= 2.1+ \; + \; 3.0+ \; + \; 3.0-$

$= \frac{2.1+}{3} = .7\%+$

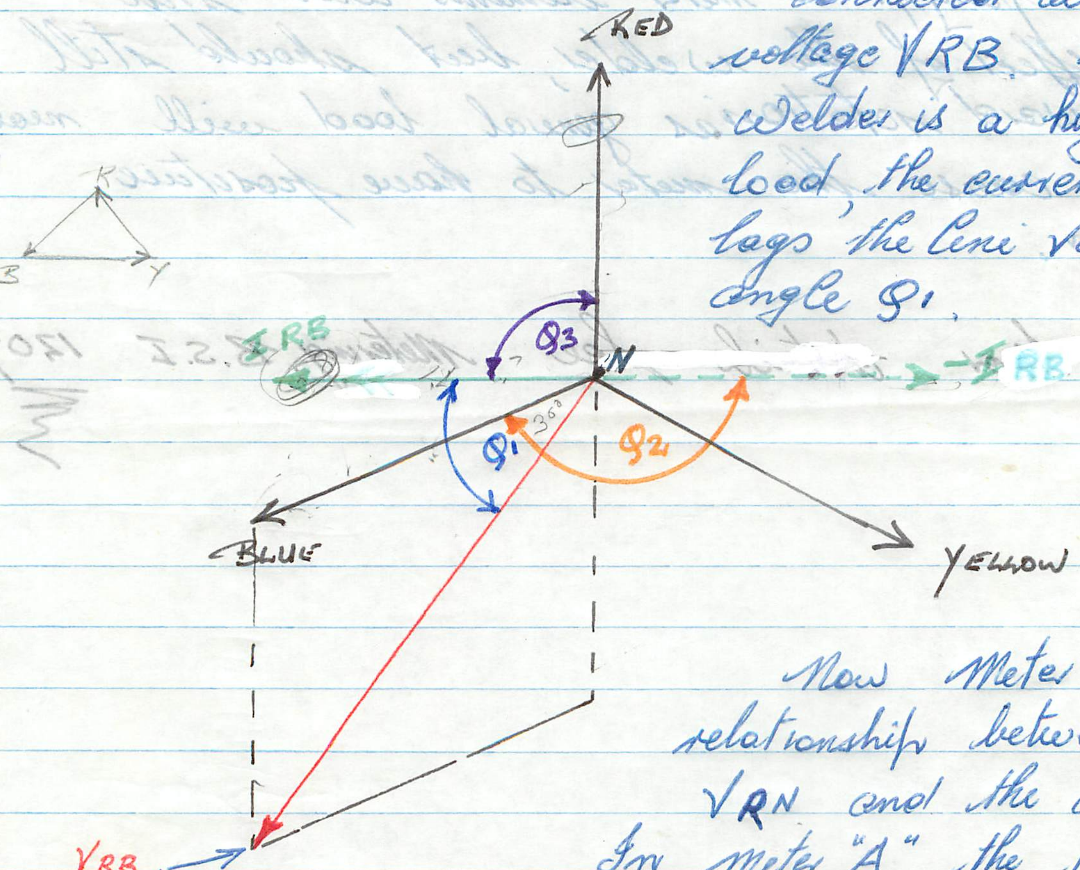
Average Accuracy would be $\frac{\text{20 Amp UPF error} + \text{20A 0.5 error}}{2}$

$= \frac{1.3+ \; + \; .7+}{2} = 1\%+.$

For domestic load, the 0.5 lag error is not applicable and the LL (1AMP UPF) error would be used as per your B.S.



Note: The welder is connected across line voltage V_{RB}. Now as the welder is a highly inductive load the current I_{RB}(→) lags the line voltage V_{RB} by angle θ_1.



Now Meter "A" sees the relationship between the voltage V_{RN} and the current I_{RB}. In meter "A" the phase angle is θ_3. In this case the angle is approx. 90°. At this angle, the meter "A" will stop. Meter "B" sees voltage V_{BN} and current $-I_{RB}$, this angle θ_2 is approx 150° and, therefore, the meter "B" will reverse as Power registered by kWh meter "B" $= V_{BN} \times I_{RB} \times \cos 150^\circ$

$= V_{BN} \times I_{RB} \times -0.866 =$ Reverse rotation.

The Accounts section will generally query meter "B" reversing and to render the account, they will assess units reversed and add to those registered, if any on Meter "A"

P.T.O

If such a case is found, the accuracy of the meter should be found by test, and all information forwarded by query card to accounts.

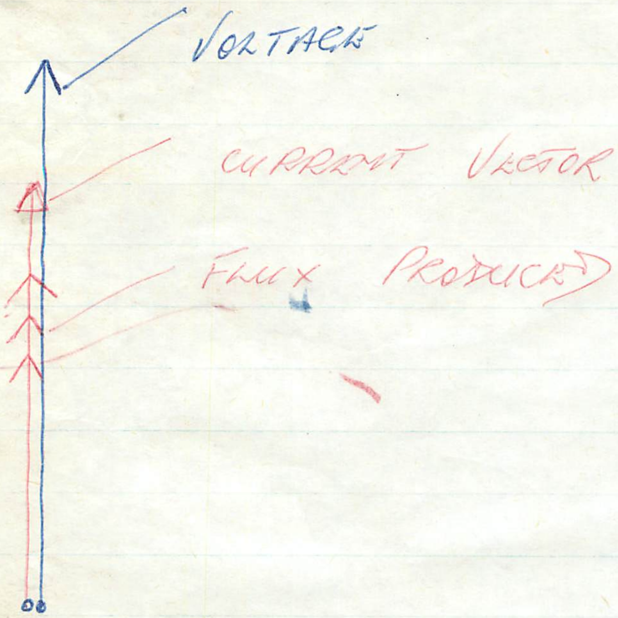
The L.H. metering, should refer such cases by MS 14 (CSS 516) to (Installation Inspectors) Customer Supply requesting the single phase meters be replaced by a polyphase meter.

The polyphase meter elements will still see the effect of the welder, but should still give forward rotation as general load will nearly always cause the meter to have positive registration.

Note: For details see Metering B.S.I 1207.

VOLTAGE → CURRENT → FLUX IN PHASE WITH CURRENT

FLUX → FLUX IN PHASE WITH CURRENT

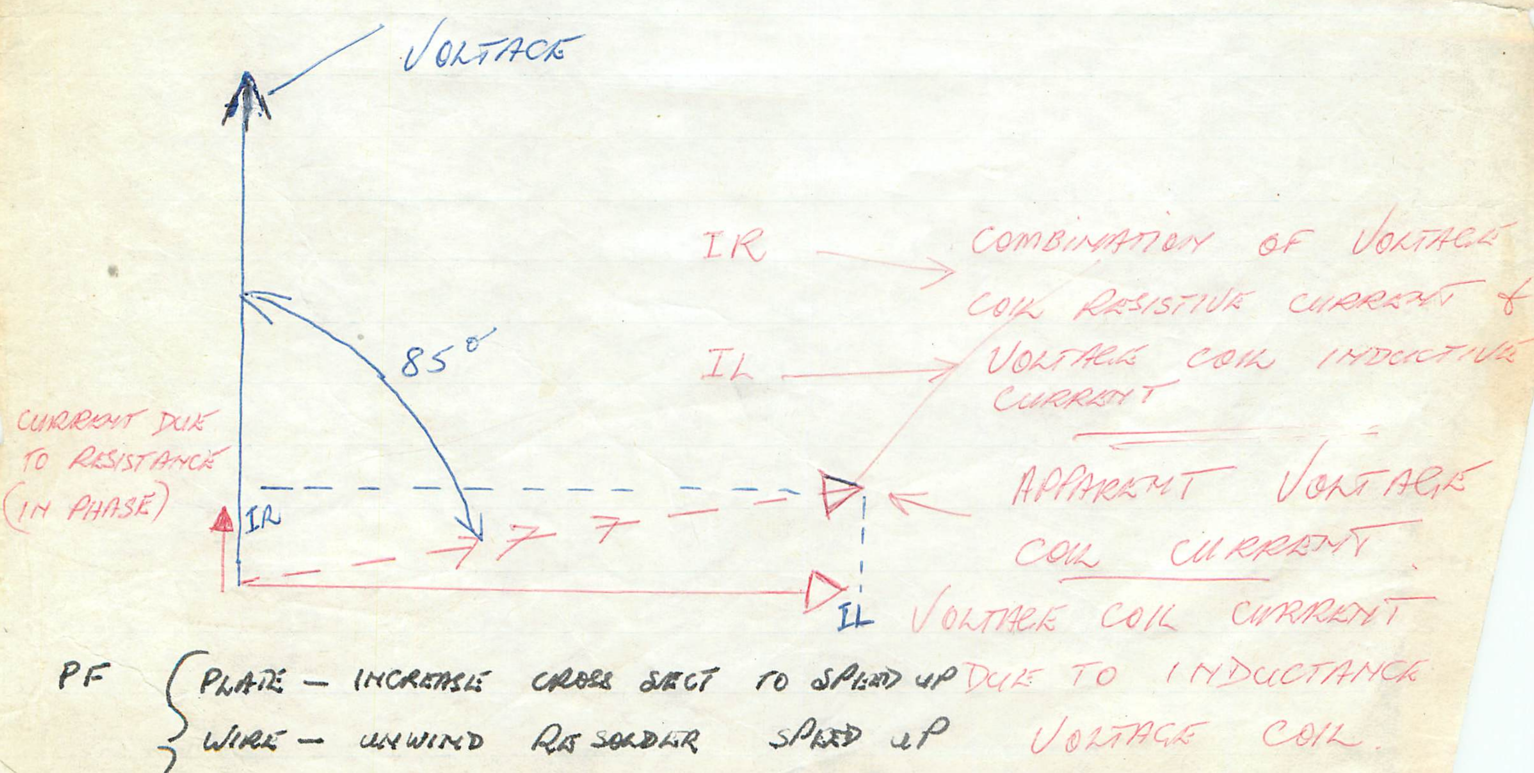


CURRENT COIL AT UNITY P.F.

FLUX PRODUCED

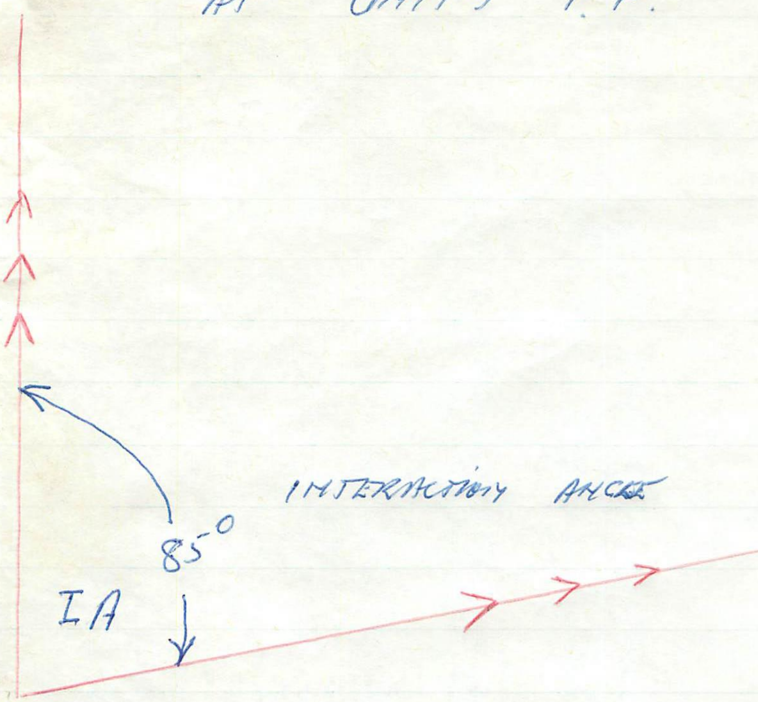
NON INDUCTIVE LOAD ∴ LINE CURRENT & LINE VOLTAGE ARE IN PHASE.

VOLTAGE COIL AT UNITY P.F. UNCOMPENSATED METER



PF
- PLATE – INCREASE CROSS SECT TO SPEED UP
- WIRE – UNWIND RE SOLDER SPEED UP
- STRIP – CUT OUT SECTIONS TO SPEED UP.

DRIVING FLUXES ON UNCOMPENSATED METER AT UNITY P.F.



MAX TORQUE PRODUCED WHEN DRIVING FLUXES ARE AT 90° TO EACH OTHER
∴ AS THE INTERACTION ∠ IS LESS THAN 90° — MAX TORQUE IS NOT PRODUCED.

TRUE POWER = E. I. Cos Ø.

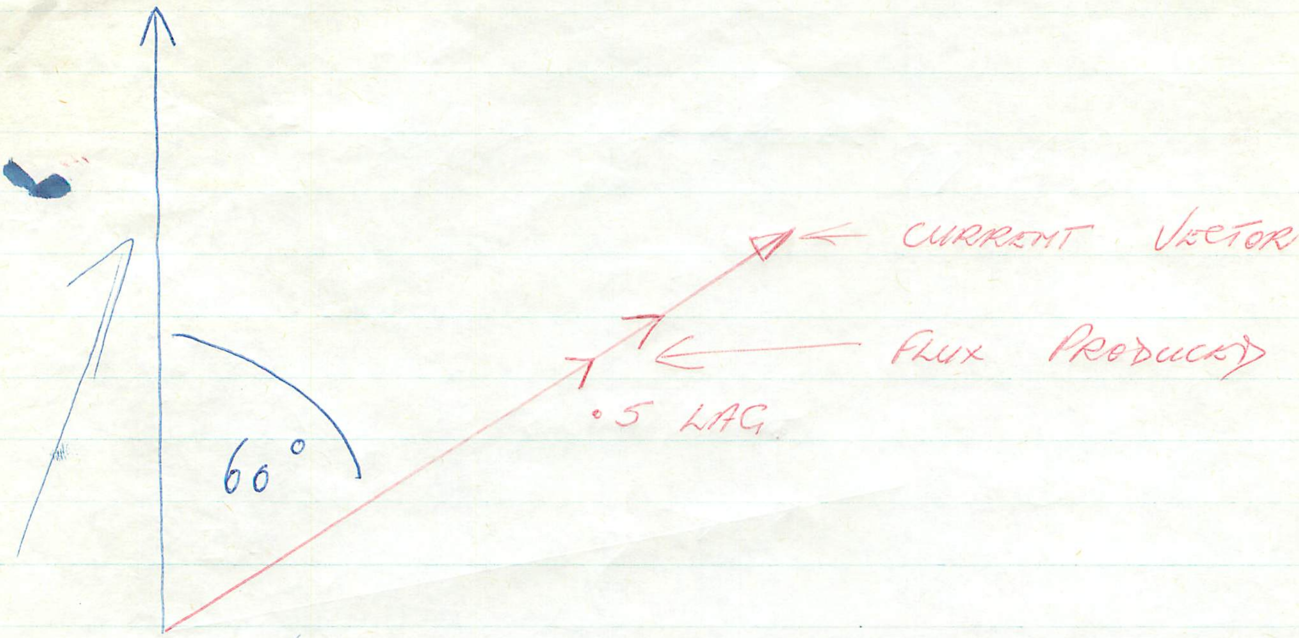
METER POWER = E I SINE $\triangle^{IA}$ INTERACTION ANGLE

E.G. CIRCUIT CURRENT 10 A.
VOLTAGE 240V
$\phi = 0$ ∴ $\cos\phi = 1$

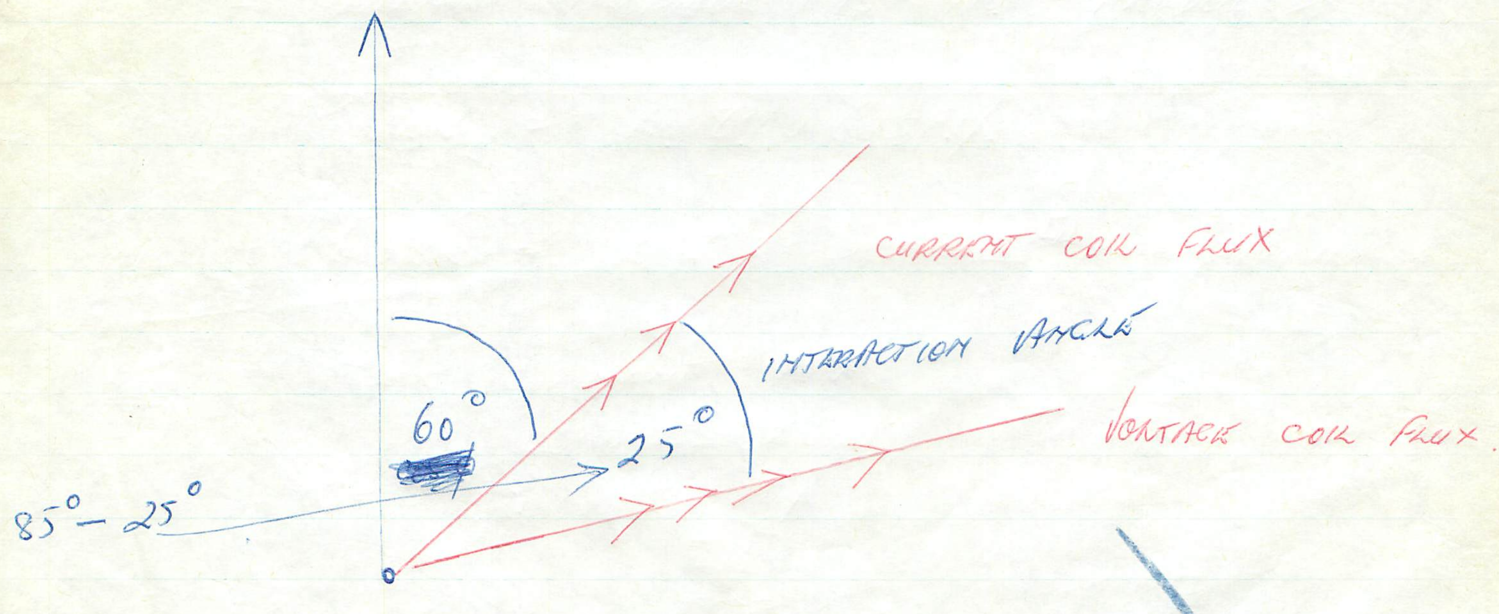
TRUE POWER = E I Cos Ø
= 240 × 10 × 1 = 2400 W.

METER POWER = E I SINE ∠ IA
= 240 × 10 × SINE 85° (.9962)
∴ METER METER SPEED IS = 2390 W (APPROX)
WHICH IS 99.58 % OF TRUE POWER. 99.6 %

LOAD CURRENT AT 0.5 LAG. ON UNCOMPENSATED METER



NOTE VOLTAGE COIL CURRENT IS UNAFFECTED BY LOAD ∴ VOLTAGE COIL FLUX WILL STILL LAG LINE VOLTAGE BY 85° IRRESPECTIVE OF THE LOAD CURRENT POWER FACTOR.



LOAD CURRENT AT 0.5 LAG.

I.E. = TRUE POWER $= 240 \times 10 \times 0.5$
$= 1200$ W.

METER POWER $= 240 \times 10 \times$ SINE 25°
$= 240 \times 10 \times .4226$
$= 1014$ W

$\therefore$ PERCENTAGE SLOW $= \frac{1014}{1200} \times 100$
$= 84.5\%$

$\therefore$ METER IS 15.5% SLOW.

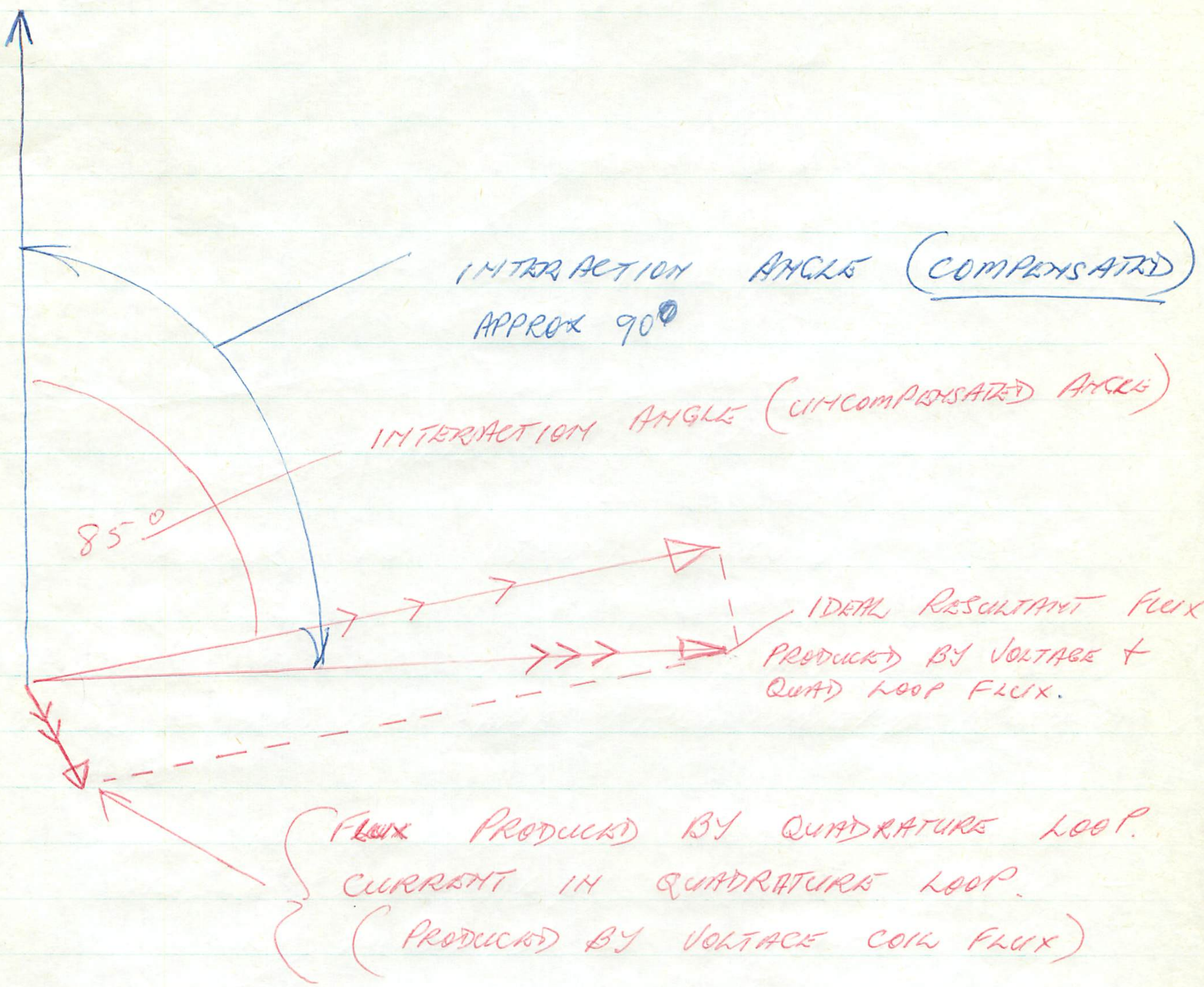
IN AN UNCOMPENSATED METER

CONCLUSION (i) LOADS OF UNITY PF (RESISTIVE) OR THERE ABOUTS ARE REASONABLY ACCURATELY MEASURED

(ii) LOADS OF LOW PF WILL GIVE INCREASINGLY GREATER ERRORS — THESE WILL ALWAYS BE MINUS.

(iii). OBVIOUSLY THE ANGLE OF INTERACTION MUST BE INCREASED TO 90° AT UNITY P.F. & WILL OF NECESSITY STAY IN STEP WITH CHANGES OF P. FACTOR.

VOLTAGE COIL COMPENSATION.



POWER IN CIRCUIT.

E.I. Cos θ

Cos θ REFERES TO POWER FACTOR.
WHEN θ IS THE ANGLE BETWEEN. CIRCUIT VOL & CIRCUIT CURRENT

θ	AT	U.P.F. (UNITY)	= 0	∴ Cos 0 = 1
θ	AT	0.5 LAG.	= 60°	Cos 60 = 0.5
θ	AT	ZERO P.F.	= 90°	Cos 90 = 0.

POWER AS METER SEES I.T. (POWER PRODUCING METER TORQUE)

BECAUSE 2 FIELDS PRODUCING TORQUE SHOULD BE AT 90° TO PRODUCE MAX TORQUE WHICH WOULD COINCIDE WITH UNITY P.F. LOAD (θ = 0) CALCULATIONS WILL HAVE TO BE BASED ON USING SIGN OF THE ANGLE BETWEEN THE 2 FLUXES.